Carnegie Mellon
Software Engineering Institute

Spiral Development and Evolutionary Acquisition

The SEI-CSE Workshop, September 2000

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A Report on the SEI-CSE Workshop, September 2000

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COTS-Based Systems

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The ideas and findings in this report should not be construed as an official DoD position. It is published in the interest of scientific and technical information exchange.

Norton L Compton

FOR THE COMMANDER

Norton L. Compton, Lt. Col., USAF
SEI Joint Program Office

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Executive Summary

The evolutionary acquisition strategy has been promulgated by the forthcoming DoD Instruction 5000.2. It introduces innovations throughout the acquisition cycle: before a contract is considered, technology readiness guides the choice of experiments; contracts are let for one or more blocks; and progress within each block is managed with spiral development. There is some confusion as to the nature of evolutionary acquisition and spiral development and their relationship. To address these problems, a workshop was held September 13-15, 2000, under joint sponsorship of the Deputy Under Secretary of Defense for Science and Technology, the Software Engineering Institute, and the Center for Software Engineering. This report summarizes the workshop and presents its recommendations.

The workshop concentrated on the application of spiral development within the context of evolutionary acquisition by asking the question "How can federal organizations use both to improve the overall acquisition process?" Sessions were organized around the following key issues:

- canonical definition of evolutionary acquisition
- successful strategies for evolutionary acquisition
- the mapping between spiral development and evolutionary acquisition
- institutional barriers to evolutionary acquisition and spiral development
- practical steps necessary to operationalize spiral development and evolutionary acquisition.

Presentations

The first day and a half of the workshop were devoted to presentations by executives and practitioners representing government, commercial users, solution providers, and contractors. In retrospect, these presentations evoked these themes and comparisons:

- The definitions of EA and SD are beginning to be understood. The basic definitions were presented in detail.
- Extensions of the definitions toward synchronization, rapid deployment, and a new role for testing.
- DoD funding and contracting policies are not SD friendly. A number of speakers mentioned this problem, but few documented it. Two offered partial solutions.
- Stakeholder teamwork is essential. Speakers cited many situations where it was invaluable.
- Education and training are essential to acculturation. Cultural change is necessary so that new approaches are not abandoned early.

Work Group Recommendations

The second half of the workshop was devoted to small work group sessions, each addressing a different topic. These groups were charged with recommending concrete actions for progress. They made 32 recommendations, falling into six categories:

Improve Contract Models	Incorporation of EA and SD in projects requires new contract clauses, new kinds of contracts, and new procedures for letting contracts.
Revise Funding Approaches	Innovative funding approaches are necessary to adapt to SD and EA.
Adapt Acquisition Policies	Acquisition policies must be adapted to suit EA and SD.
Enhance Integrated Product Teams	IPTs must be given authority and status to match their responsibility.
Provide Training	People need new skills to deal with EA and SD. These skills can come from post-secondary education, service-wide training, and training within specific projects.
Study SD and EA	SD and EA require further study in order to validate and improve the processes.

For each recommendation, the work group proposed an action agent, the person or group most appropriate for taking the necessary actions and a date by which that action ought to have occurred.

Abstract

The evolutionary acquisition strategy has been promulgated by the forthcoming DoD Instruction 5000.2. It introduces innovations throughout the acquisition cycle: before a contract is considered, technology readiness guides the choice of experiments; contracts are let for one or more blocks; and progress within each block is managed with spiral development. There is some confusion as to the nature of evolutionary acquisition and spiral development and their relationship. To address these problems, a workshop was held September 13-15, under joint sponsorship of the Deputy Under Secretary of Defense for Science and Technology, the Software Engineering Institute, and the Center for Software Engineering. This report summarizes the workshop and presents its recommendations.

Themes appearing in the workshop presentations included the lack of understanding of the definitions of evolutionary acquisition and spiral development, some extensions to these definitions, the barriers imposed by existing funding and contracting policies, the need for teamwork among all stakeholders, and the role of education and training in acculturation. Work groups at the workshop recommended specific actions aimed at building and spreading a culture for evolutionary acquisition and spiral development. These actions can be grouped under the topics of improvements to contract models, revision of funding approaches, adaptation of acquisition policies, enhancement of integrated product teams, training and acculturation of participants, and studies of evolutionary acquisition and spiral development to validate and improve them.

1 Introduction

The recent DoD revisions to the 5000.2 series have introduced evolutionary acquisition (EA) as the appropriate method of operation for acquiring new and enhanced systems. The approach begins with a series of explorations to ensure technology readiness and then proceeds to doing spiral development (SD) in each of a number of funding blocks. To study and popularize the new policies, a workshop was conducted September 13-15, 2000, under the aegis of Dr. Delores Etter—the Deputy Under Secretary of Defense for Science and Technology (DUSD/S&T)—and the sponsorship of the Software Engineering Institute (SEI) of Carnegie Mellon University and the Center for Software Engineering (CSE) of the University of Southern California. This report is the result.

Dr. Etter opened the workshop with a keynote address describing the challenges to DoD systems and software development. Later presentations included one from Dr. Barry Boehm defining the SD and another from Dr. Jack Ferguson describing the new DoD 5000.2 policies. The workshop was organized around five topics, as listed in Table 1. This table also lists the presenters who spoke to each topic on the first day. The second day was devoted to five work groups, each addressing one of the topics. The third morning featured presentations from the five groups and a summary by Steve Cross, Director of the SEI.

Section 3 presents an overview of the workshop themes.
- Indented blocks in this font are from the slide presentations

The fourth section summarizes the recommendations from the work groups and the next section presents their findings. A final section compares this workshop with a prior workshop on spiral development held in February 2000. An appendix provides a sorted list of the recommendations. Supplementary material, including the presentations, can be found on the workshop Web site:

http://www.sei.cmu.edu/cbs/spiral2000

The Workshop met in the large conference hall on the first floor of the Arlington, Virginia, building that houses the SEI. The five dozen attendees were seated at five rows of six tables with a central aisle. Time was managed with a PowerPoint application showing the minutes remaining; when time expired, it sounded a bell.

Presenters covered both the government and the contractor sides of acquisition, with a few speakers from the commercial sector to give external viewpoints. There were no representatives from organizations to which acquired systems would be deployed. There were numerous references to systems developed with SD, but only one—the Joint Expeditionary Forces

Experiment (JEFX) as described by Tillotson—was described in enough detail to make discernible its spiral development aspects.

Table 1: Presentations at the Spiral Workshop

Keynote speaker
Dr. Delores M. Etter, DUSD (S&T) – *Spiral Workshop*
"Definition" - Canonical Definition of EA
Barry Boehm, USC - *Spiral Development & Evolutionary Acquisition: Where Are We Today?*
Jeff Rothenberg, Rand - *Spiral Development & Evolutionary Acquisition*
Jack Ferguson, OSD - *Spiral Workshop*
"Mapping" - The Mapping between SD and EA
Maj. Ross McNutt, USAF - *Reducing Air Force Acquisition Response Times: Evolutionary Acquisition and Spiral Development*
Eliot Axelband, USC - *Comments/Observations/Suggestions*
"Strategies" - Successful Strategies for EA
Charles Leinbach, C-Bridge - *c-Commerce and Spiral Development*
"Barriers" - Institutional Barriers to EA and SD
Stan Levine, US Army - *Implementing System of Systems in a Spiral Development/Evolutionary Acquisition Environment*
Don Andres, TRW - *Evolutionary Acquisition & Spiral Development: Barriers*
"Operationalization" - Practical Steps Necessary to Operationalize SD and EA
Michael Bloom, MITRE - *Spiral Development in DoD: Get out of the box!*
Tony Jordano, SAIC - *SAIC - Spiral Development*
Larry McKee, MITRE - *Spiral Development: A User's Perspective*
Col. Dave Tillotson, USAF - *Joint Expeditionary Forces Experiment (JEFX)*

2 Keynote Speaker: Dr. Delores Etter

In her keynote, Dr. Delores Etter described DoD acquisitions in Research, Development, Testing and Evaluation (RDT&E), the efforts to ensure a maximum national security payoff from these acquisitions and, more broadly, the methods used to acquire systems throughout the armed forces. As Figure 1 shows, over 40 billion dollars will be invested this year in RDT&E, with a bit over 20% going to Dr. Etter's area of Science and Technology (S&T).
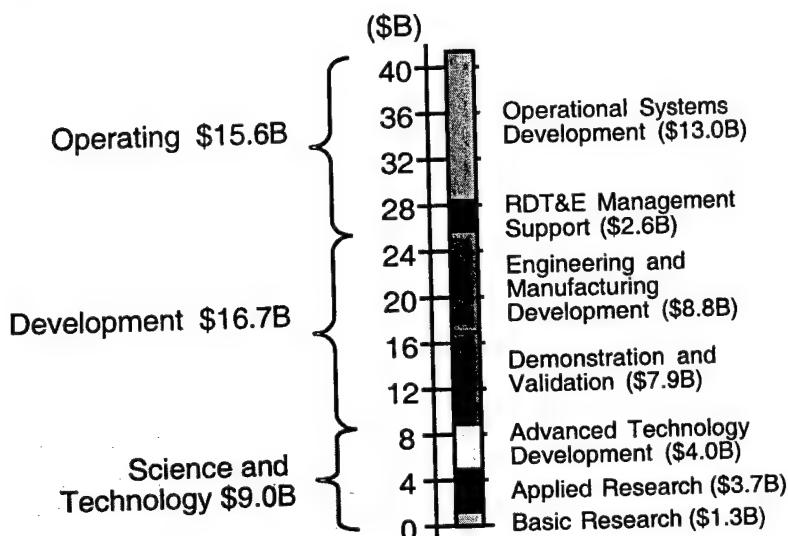
Figure 1: Fiscal Year 2001 Spending on RDT&E, $41.3 Billion

In fiscal year 2001, spending on S&T is about equally distributed among the services and Defense Advances Research Projects Agency (DARPA). Despite an era of decreasing defense budgets, S&T spending by the services has remained more or less steady over the last decade, as shown in Figure 2.
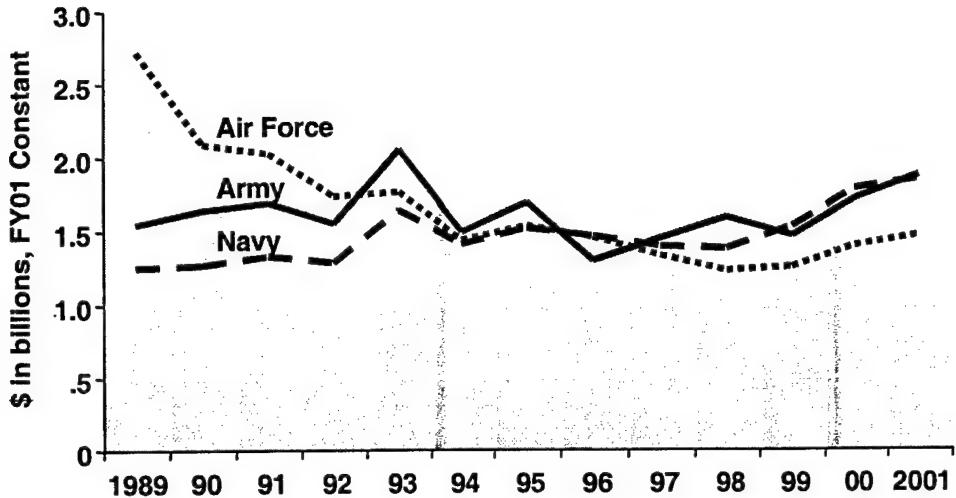
Figure 2: Annual Spending by the Services on Science and Technology

Although Air Force spending has declined in S&T, its total spending on RDT&E remains far above that of the other services on a per-warrior basis. Figure 3 (not from the presentation) shows the total obligation authority of the three services as a number of dollars per personnel-dollar. The RDT&E spending is 18, 32, and 65 cents per personnel dollar for the Army, Navy, and Air Force, respectively. These factors reflect the facts that the Navy and Air Force are more asset-intensive than the Army, and the Air Force has a lower ratio of officers to enlisted personnel (AF:1.1, Navy: 2.6, Army: 1.6).

National Defense Budget Estimates FY01
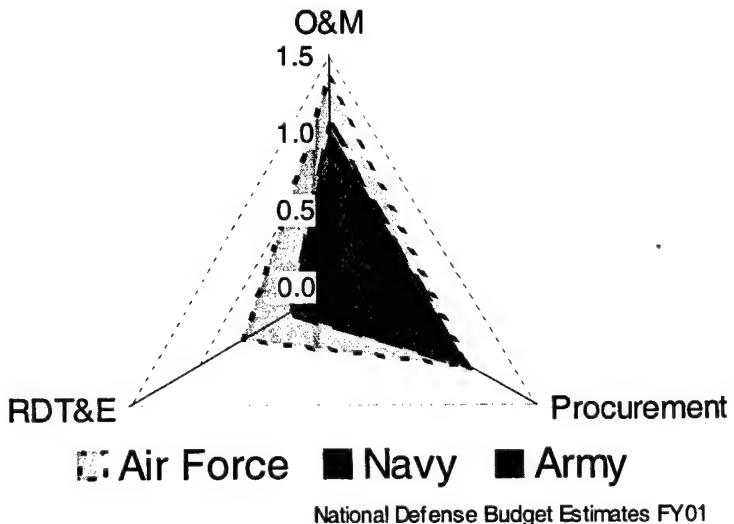
Figure 3: FY01 Spending ($ per Personnel $)

Dr. Etter views DoD Science and Technology as a partnership among DARPA, the universities, the service laboratories, industries, interagency efforts, and international coalition cooperation. She sees these groups as approaching software intensive systems from five directions. In the following list, the examples are chosen from her presentation:

- Policy: Acquisition Reform Legislation; AT&L 5000 Rewrite
- Discipline: Capability Maturity Model® Integration (CMMI^{SM}); Improving DoD Software Metrics
- Collaboration: Office of the Under Secretary of Defense of Acquisition, Technology and Logistics OUSD(AT&L) Tri-Service Assessment Initiative
- Career Development: Developing a training course for S&T managers in the acquisition of software-intensive systems
- Science and Technology: Building and strengthening relationships with researchers in software engineering technology and education

Turning to evolutionary acquisition and the workshop, Dr. Etter pointed out that "Getting evolutionary acquisition to succeed for DoD software-intensive systems requires new directions and harmonizing" these areas:

- software acquisition practices
- milestone definitions
- maturity models
- metrics
- product line management
- process and architecture technology
- education and training

Considering all these aspects, she concluded that:

Evolutionary Acquisition is the way DoD must go

to provide needed capability to the warfighter

in a timely manner

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^{SM} CMMI is a service mark of Carnegie Mellon University

3 Themes

A number of topics appeared in multiple presentations, work group recommendations, and comments after the workshop. This section collects together these themes:

The definitions of EA and SD are beginning to be understood.

The definition of SD should be extended.

DoD funding and contracting policies are not SD friendly.

Stakeholder teamwork is essential.

Education and training are essential to acculturation.

Each theme is discussed in a following subsection.

3.1 The Definitions of EA and SD Are Beginning to Be Understood

A fundamental basis of a workshop on spiral development and evolutionary acquisition ought to be a firm understanding of the definitions of each of these terms. The workshop did indeed shed light on them.

Evolutionary Acquisition: The DoD 5000 series—DoD Directive 5000.1, DoD Instruction 5000.2, and DoD Regulation 5000.2R—was rewritten under Dr. Etter in the office of Software Intensive Systems under Jack Ferguson. On the second morning of the workshop Ferguson discussed these documents and their new "Evolutionary Acquisition" approach. He began with the objectives of the rewrite:

- Develop a new acquisition model that reduces cost and cycle time while delivering improved performance.
- Move DoD closer to a commercial-style approach.
- Implement Section 912 recommendations.
- Implement other reports and key initiatives.
- Further streamline the acquisition process.

Here the "Section 912 study" refers to a study mandated by Congress to examine acquisition. It had a major focus area of "cycle time," the length of time taken to perform an acquisition. The fact that this is a problem is evident in that both Ferguson and McNutt presented Figure 4 showing that the cycle time from program initiation until "IOC" is approaching a decade. It must be understood here that IOC is not the completion of the project, but is instead the Initial Operational Capability, that is, the first time anything is made available to the troops in

the field. It is suggestive that the curves are an inverse of the spending curves in Figure 2, but neither presenter commented on this.

Source: DSB Briefing, Dan Czelusniak, 12 June 1998
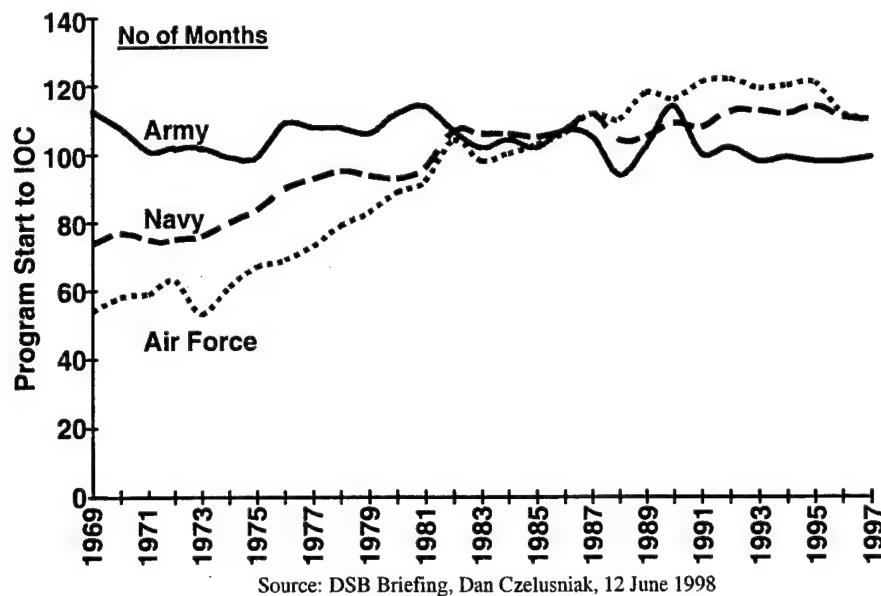
Figure 4:   Average Time from Program Start to IOC

Ferguson emphasized these aspects of the 912 study's focus on acquisition cycle time:
- Time-Based Requirements
- Delay Freezing of Requirements
- Requirements Set at Milestone II not Milestone I
- Evolutionary Acquisition as Norm

Turning to evolutionary acquisition itself, Ferguson showed the definitions from two Air Force documents:

Evolutionary Acquisition (EA) - An acquisition strategy to adapt to a changing environment by *rapidly acquiring* and sustaining a supportable *core capability* and incrementally inserting *new technology or additional capability* [SAF/AQ 00].

Evolutionary Acquisition (EA) - An acquisition strategy whereby a basic capability is fielded with the intent to develop and field additional capabilities *as requirements are refined*.[SAF/AQI 00].

In DoDI 5000.2 [USD(AT&L) 01], evolutionary acquisition is defined thus:

In an evolutionary approach, the ultimate capability delivered to the user is divided into two or more blocks, with increasing increments of capability. Deliveries for each block may extend over months or years. Block 1 provides the initial deployment capability (a usable increment of capability called for in the ORD). There are two approaches to treatment of subsequent blocks:

The ORD includes a firm definition of full capability, as well as a firm definition of requirements to be satisfied by each block ...

or

> The ORD includes a firm definition of the first block, but does not allocate to specific subsequent blocks the remaining requirements that must be met to achieve full capability. …

The full scope of the 5000 acquisition process extends from initial notion all the way to multiple successive fieldings of the program. The concept of technology readiness, as defined by a Government Accounting Office report [GAO 99], is utilized to test technologies to prepare them for actual acquisition. As shown in Figure 5 the technology is hatched somewhere and adopted as an S&T project to try it out. If successful there, it becomes the subject of ATD, ACTD (Advanced [Concept] Technology Demonstration), or JWE (Joint Warfare Exercise). Somewhere in this phase a decision is reached to actually acquire a system embodying the technology.
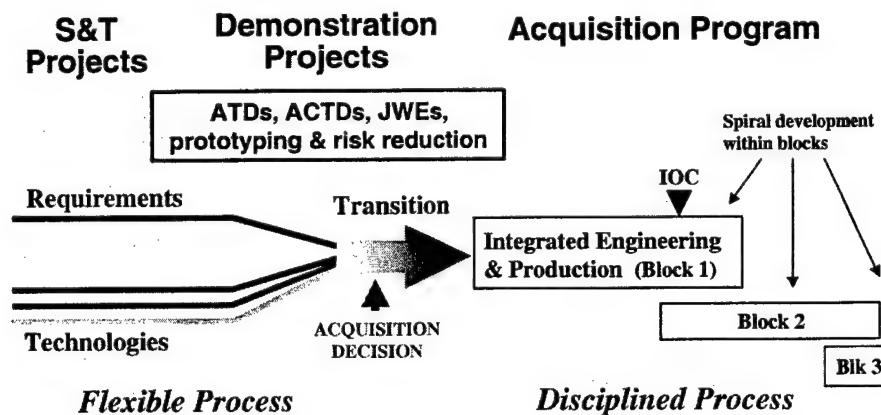
Figure 5: DoDI 5000.2 Acquisition Process: from Idea to Fielding

It is at the Acquisition Program phase that evolutionary acquisition commences. The key concept is that the acquisition occurs in a sequence of blocks, with each block culminating in fielding some fraction of the program's capability. That capability is sketched in the contract for the block, but is probably not spelled out completely in order to give scope for the decisions of the spiral development risk-management team. Indeed, Ferguson noted that

- Evolutionary Acquisition implies evolutionary requirements
    Directed in CJCS Instruction 3170.01A Requirements Generation System

- Evolutionary Acquisition
    also implies evolutionary fielding
    with impacts on training and sustainment

Within blocks of evolutionary acquisition, DoDI 5000.2 specifies an "iterative spiral approach" be used for development.

Spiral development was fully defined in Boehm's talk, a refinement of his talk at the February workshop. (His talk also described the results of the first workshop.) Boehm defined spiral development as

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- A risk-driven process model generator
- Used to guide concurrent engineering
- Two distinguishing features:
    - cyclic approach for growing system definition
    - anchor point stakeholder-commitment milestones

He went on to specify six attributes that are "invariant" in the sense that every spiral process ought to have them. In an extension of the February presentation, he showed how IEEE 12207.2-1997 [IEEE/EIA 98] helps to choose among the various acquisition models. This choice is made in each cycle of a spiral development, based on the risk factors deemed of highest priority at the start of that cycle.

Despite all these efforts at defining the process models, there was still some confusion. After the conference, attendee Peter Hantos from Xerox remarked that

> I think many people were not clear on the connection between EA and SD. ... Getting straight the basic terminology was also a common [question]. (What is a software-intensive system, what is the reference definition of spiral development, why is the acquisition "evolutionary," and how does it relate to the evolutionary spiral development, etc.) ... Surprisingly there was a lot of debate on very basic definitions.

3.2 Extensions to the Definition of SD

A number of speakers echoed or extended the definitions of spiral development. McNutt reiterated Ferguson's definition, emphasizing the role of spiral development in each iteration. In a further refinement, McKee described a "CAOC-X" unit in the Air Force that will serve as a testing area and will help manage the spiral development of each project. From a contractor perspective, Jordano showed how spiral development is institutionalized by the corporate process group. There is a definition of spiral development and a catalog of criteria to use to determine if spiral development is correct for any particular project.

Two speakers emphasized that spiral project development does not occur in a vacuum; there is a persistent need to synchronize the activities in the spiral development with those in other development projects. Rothenberg phrased the problem this way:

- We split complex endeavors into simpler activities to "divide and conquer" them.
- But the resulting activities are not motivated or funded to look beyond their own boundaries.
- So they ignore external changes that undermine their assumptions and decisions.

He illustrated the problem with the example of the Abrams tank project, Figure 6. The Program Manager (PM) for this project must deal with concerns from (at least) three other PMs, four Program Element Officers (PEOs), and three multinational arenas.
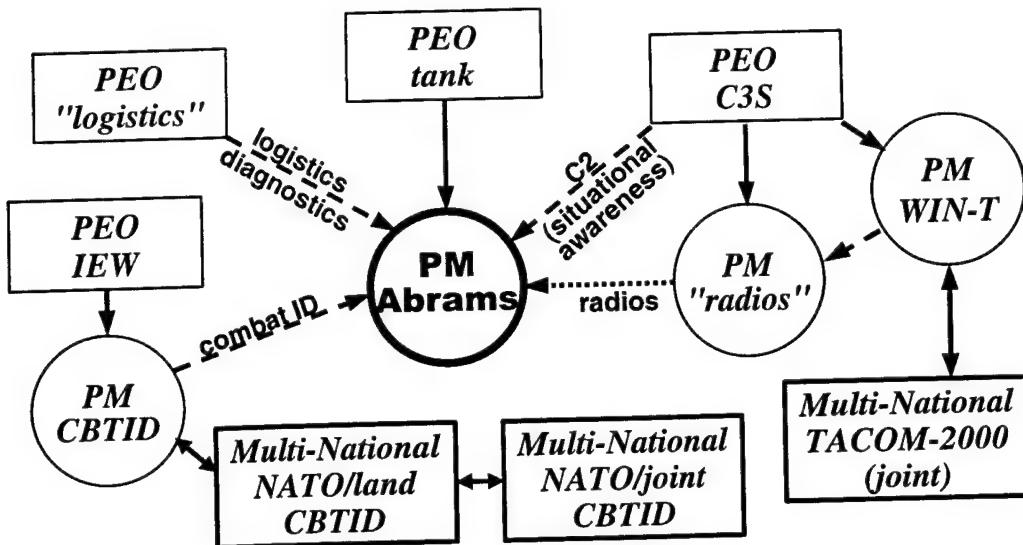
Figure 6: External Programs with which the Abrams Tank Must Synchronize

Rothenberg defined an enhanced spiral cycle to deal with this sort of problem. To over-simplify, each spiral cycle has five steps (where asterisks indicate additions to a normal spiral process):

- Define alternatives, *consider external factors.
- Evaluate alternatives, based on risk; choose one.
- Perform this cycle's work.
- Evaluate and *post results; plan next cycle, *synchronize, and commit.
- *(Re-) Identify external factors and stakeholders; negotiate reconciliations.

In a similar vein, Levine noted that

- The Army must synchronize "System of Systems" mission threads and interoperability requirements across the Army and then on to Joint and Coalition levels.

In elaboration, he presented material in each of these areas:

- Requirements Synchronization
- System Design Synchronization
- System Implementation Synchronization
- Operational Integration Activities

Sometimes the need for synchronization is expressed as "concurrent engineering." Boehm mentioned that spiral development is "used to guide concurrent engineering," and Bloom noted that a "Concurrent Engineering Approach" is essential to

- Understand the problem and try potential solutions

This approach must be applied in four areas: system context, architecture/design, legacy system, and marketplace.

Although not strictly a part of the definition of evolutionary acquisition, several speakers talked about the anticipated role of that approach and spiral development in reducing the time to complete projects. The approach is actually realistic to the extent that it does not mean getting the project "done" sooner, but rather the expectation is that partial results can be deployed to the field earlier in the development process. McNutt's entire presentation was on the ongoing effort to reduce the "cycle time" to field a project. As part of this he presented a method for analyzing the "cost of delay," which he showed to far outweigh other considerations in some cases. He expects evolutionary acquisition and spiral development to play a key role in cycle time reduction. Levine agreed and stated that combining the two

- Accelerates acquisition and provides recurring improvements to systems fielded to our warfighters

Leinbach observed the same need for faster delivery in the commercial sector where the customers "need fast business deployment," and get it through his company's "RAPID™" process, which provides

- Application delivered much sooner at less cost

- First release available very quickly

In other words, evolutionary acquisition fields an early version of the system, which is operational, but probably without full capabilities. Typically, it is *not* expected in DoD 5000 that each spiral will field its results, although that is common in spiral development projects.

The role of testing was another area where spiral development was extended. In DoD acquisition, testing has come to be done by an independent organization operating after the system is delivered. This makes sense for large military hardware systems, where the military alone is equipped to assess the battlefield capabilities of a tool. For software, however, test-at-the-end tends to delay rather than inform the acquisition process. Tillotson noted this in his summary where he remarked

- Assessment or test must be part of initial planning

In remarks written after the workshop, Bloom said:

> *Testing is "broken" for C4I (Command, Control, Computers, Communications and Intelligence) systems. Application of preproduction testing techniques designed for an "iron" world are barriers to timely fielding of software updates. A risk-based—not risk-averse—approach needs to be developed and employed similar to that used by commercial organizations like Microsoft.*

Bloom devoted half of his presentation to the need for and possibilities of testing as part of spiral development. He created a parable-picture with the task of moving cows from one hilltop field to another. The legacy system is a trail through the valley and the modern system is a bridge. The role of testing in spiral development, he says, is to test those portions of the system that are released in each iteration. There is no need to gamble by switching everything to the new system immediately. For the cows, we can do tests of the initial release by sending only one across the bridge, as in Figure 7.
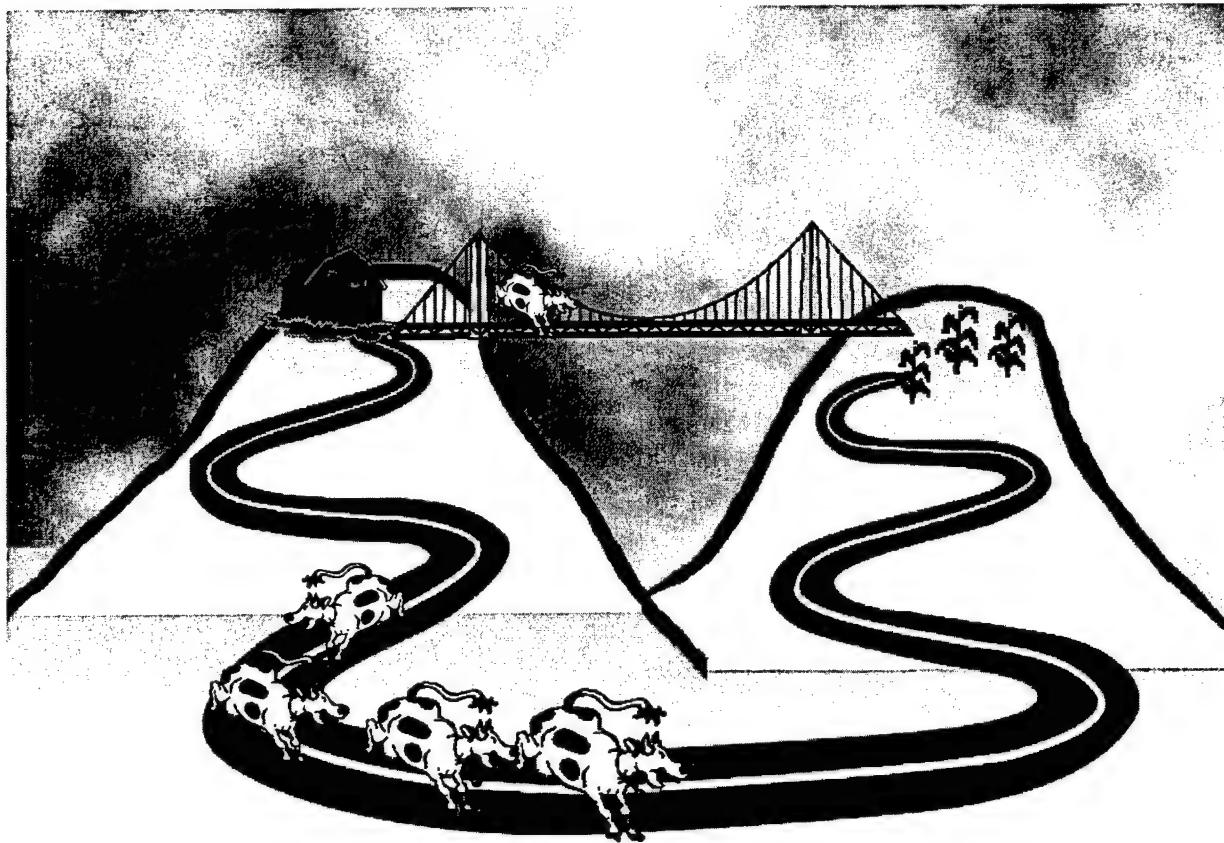
Figure 7: Testing the New System with Only a Portion of the Load

Bloom's point was that it is time to combine testing considerations with risk management. He said that testing should be

- Continuous rather than end of block
- Subject to a risk assessment (vs. benefit of testing) for the type of product and its intended environment
- An integral part of experimentation to capture the utility and underlying need for successful prototypes
- Used to establish an expanding operational "flight envelope" as a new capability matures in terms of functionality, reliability, usability, efficiency, maintainability, interoperability, security...

Andres	• Funding constraints (Fiscal Year, PPBS, POM process, Colors and Hues of Money, etc.)
	• Changing DoD personnel - every three years
	• Risk adverse operating philosophy
	• Becoming too-Process-focused Vs. Product-focused
	• Cumbersome DoD reporting mechanisms
Axelband	• Need to establish how Spiral works contractually in a fixed price environment
	• Industry will not accept fixed price spiral development
Ferguson	• Restructure and strengthen contract incentives
Jordano	• EA and SD is not a good match for typical fixed price contracting
Levine	Evolutionary acquisition needs
	• Flexible funding process
McKee	Challenges include
	• Laws, Policy, and Rules
McNutt	Project approval time is lengthy:
	• 24 separate reviews within the Air Force Pentagon alone - process takes two to five years to complete
Clyde Ellis (Quantum Research International)	Budgeting, financing, contracting, and other support systems need to be further reformed. … EA requires direction and harmonizing of acquisition practices (policy, collaboration, career development, and discipline).

Despite this almost universal agreement that problems exist, there were few suggestions at the workshop of steps that need to be taken or are being taken. Two speakers did present the following.

Ferguson explicitly noted that
  • Evolutionary Acquisition implies evolutionary requirements
    Directed in CJCS-I 3170.01A Requirements Generation System

In other words, contracts can and must be written without complete specification of all requirements. It seems then, although Ferguson did not say so, that no project contracted for under these provisions can ever "fail." The contract specifies a general goal, a set number of dollars, and a set time. It is the task of the spiral development management team to plan work toward that goal so that it fits within the time and resources available. In a sense, all contracts become contracts for time and materials.

McNutt noted that one problem is that funds are continuously stretched and reallocated to cover whatever projects seem important at a time. This means an uncertainty in completion of any one project and an accumulation of incomplete projects. He recommended an alternate approach:

- Require all projects that are initiated to be fully funded based on development related requirements.
- Establish an effective project screening process.
- Limit the number of projects in each phase of development.
- Clear the logjam of current projects.
- Ensure necessary funds are available to accelerate projects as opportunities arise.

One way to reduce the project initiation time, McNutt suggested, is to overlap the planning of a project with the technology readiness preparations that precede letting of a contract, as shown in Figure 8.
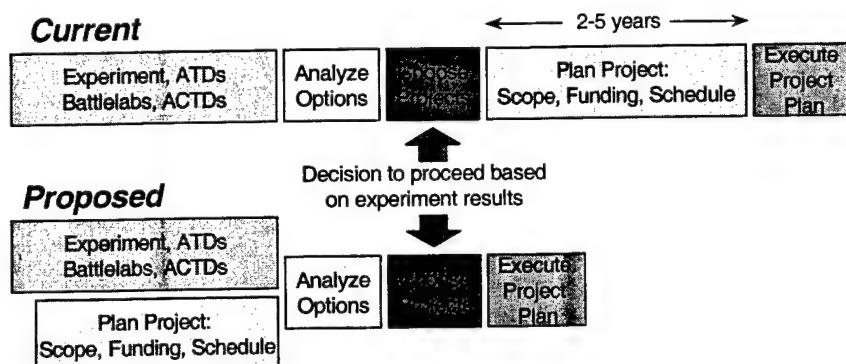
Figure 8: Project Initiation: Current Leviathan and Proposed Dolphin

3.4 Stakeholder Teamwork Is Essential

Risk management is vital to spiral development, but no single individual can cope. Risks must be managed by a team in order to discover all the ramifications of any decision. Teamwork must extend outward from the team doing risk management to all other participants so an unadulterated stream of information percolates upward and illuminates all risk considerations. This need for teamwork was emphasized by a number of speakers:

Jordano in his summary remarked
- PMO And Contractor Need To Work Together As Partners.

Levine said (emphasis in the original):
- The Army and OSD must establish an acquisition atmosphere that encourages its multiple PEOs, PMs, and contractors to collaboratively work together.

Tillotson talked about using a spiral approach to manage the development of the entire JEFX project, involving hundreds of separate experimental systems/development projects and thousands of personnel. The spiral approach, he said, had these advantages:
- Early user involvement
- Promotes Teamwork

He added that tight user involvement was the key to

- Timely and focused system changes
- Transition of results to the field

Andres had the most to say about the need for teamwork. First of all, he said, there is a need for a common vision shared by all members of the project:

- A common visionary goal needs to be established that is *common to the partnership* - Users, SPO, Contractor.
- The definition of the end target must be understood.
- Common expectations, evolution plan

However, he observed a number of impediments to such a vision and shared teamwork:

- Near-term desires vs. long-term strategic goals
- Changes in the vision with no plan
- Multiple customers/users
- Not putting the right team in place - contractor
- Associate contractor agreements (ASCONs)

Despite the near-universal agreement on the need for teamwork, no speaker had much to say about how to attain this state. The work groups, however, made a number of recommendations in this area.

3.5 Education and Training Are Essential to Acculturation

Given its huge number of personnel, the DoD has an extensive training budget and effort. It also harbors a number of cultures and traditions. Sometimes the two conflict. Nonetheless, training is one of the few avenues open to DoD to affect traditions and culture and, in general, the behavior of its personnel. Workshop attendees and presenters noted a number of situations in which traditions and culture are detrimental to achievement of the gains expected from spiral development and evolutionary acquisition. They also noted the value of training in enhancing those gains.

Jordano summarized by demanding training of both the acquirers and the "acquirees":

- Acquisition Agency and PMO Need To Be
    - trained and mature
    - at Least Level 2 of SA-CMM (Software Acquisition CMM)
- Contractor Needs To Be
    - trained and mature
    - level 3 of SW-CMM (Software development CMM)

Joe Ferrara (SEI) later presented this approach to such training:

*Not surprisingly, all the work groups said something about education and
training. This is critically important. I think SEI/CSE should arrange to meet
with the Defense Acquisition University (DAU) to discuss this point. I like the
idea of tailoring courses to different stakeholders. Also, as part of the education
process, I think exchange programs within government and between government
and industry can be helpful. For example, given the complaints about the budget
process, it would be useful to have an acquisition manager spend a year as a
budget examiner to experience the pressures and group norms. Similarly, it
would be enlightening to have a budget officer spend a year in a program office.
This could be a longer term program aimed at improving understanding across
communities.*

Thomas Bono (MITRE) remarked:

The signing of policies such as DoD 5000, AFI 63-123, and other regulations does not
institutionalize them in the SPOs that execute acquisition. PMs tend to revert back to
what they know how to do best if not properly made aware of policies and given train-
ing, step-by-step instructions, and artifact examples.

However, McNutt felt that as far as "institutionalizing EA and SD" we have

- Made good progress, but still have ways to go to
  - incorporate into acquisition processes
  - institutionalize in our processes

- Good progress with AF Acquisition Community, Contractors, OSD(A&T)

- Only to convince the planning, requirements, programming, costing, MAJCOM,
  training, sustainment, test, finance, administration, congress, GAO, CBO, AFIA, ... :-)

An important aspect of the culture is the "rice bowl" mentioned by McKee:

- Culture and "Rice Bowls"

This has reference to the practice of senior leadership personnel ensuring that funds are found
to support their special project groups, regardless of the actual need for these groups. McKee
expanded on this point in remarks made after the conference:

*Culture is perhaps the most difficult and time-consuming piece of the puzzle. We need
documented case studies to convince and tell the story. It will not happen overnight.
Significant "proof" of this can even be found in many of the introductory briefings
given—a lot of "obstacles" identified. While perhaps valid, they are in my opinion
mostly cultural issues—merely bumps in the road if we stay the course. As identified in
the end - policy, regulations, etc., all permit SD. So why aren't we doing it? Pure and
simple—age-old resistance to change, fear of the unknown, insecurity (job, ego, etc.),
etc.*

4 Summary of Recommendations

A major goal of this workshop was to foster further work in the field, directing it to ends that appear fruitful. To this end, each work group recommended one or more appropriate actions. In this summary, the recommendations are considered in five classes: Improve Contract Models, Revise Funding Approaches, Adapt Acquisition Policies, Enhance IPTs, Provide Training, and Study SD and EA. The full recommendations are in the work group reports in Section 5 and are collected in the appendix. Summaries of each class follow.

Improve Contract Models

Incorporation of EA and SD in projects requires new contract clauses, new kinds of contracts, and new procedures for letting contracts. The Barriers work group recommended that Defense Contract Management Agency (DCMA) and OSD develop contract models, including even suggested wording for contract performance incentives. There should also be incentives to encourage sharing information and work products among contractors. In a cautionary dissent, the Mapping group noted that SD is incompatible with programs that are fixed price or use strict earned value tracking.

Revise Funding Approaches

The Barriers group began with the assertion that there are no changes needed to legislation or regulation in order to allow contract innovation that will encourage adoption of SD and EA. Nonetheless, the group suggested several innovations that should occur within the existing strictures. For instance, budgets should have funding to support stakeholder participation. The central need is more funding flexibility because the risk evaluation in each spiral cycle may reveal urgent tasks and because spiral cycles may not mesh well with funding cycles. The needed flexibility may be acquired for C2 projects by combining funding at the PEO level instead of fragmenting it down to the PM level. Any such leeway in funding approach will be unrecognizable to the financial management community, and so they, too, must be educated and enrolled in the drive to reach the advantages of EA and SD.

Adapt Acquisition Policies

Although DoDI 5000.2 has begun a process of adaptation of acquisition policy, the work groups suggest that the task is not yet complete. As adaptations proceed, they recommend that changes be coordinated by a single office or IPT and that this group prepare a plan for rollout of and transition to the new approaches. In all this planning and adaptation, DoD

should seek the advice and involvement of industry, International Council on Systems Engineering (INCOSE), and Project Management Institute (PMI).

The Mapping group had a number of suggestions in terms of adaptation of the EA and SD policies. They recommended incorporating robustness and adopting anchor point milestones. They suggested that EA is too often represented as a linear process and should instead be shown in its true, iterative nature. Finally, they pointed out the necessity of distinguishing between information systems (e.g., logistics or C2) and software intensive systems (such as weapons acquisitions).

Enhance IPTs

A number of suggestions addressed integrated product teams (IPTs). Their number should be limited to enhance their power and reduce the number of personnel commitments. The size of each must be kept manageable, and yet the definition of stakeholder needs to be broadened to include representation from groups such as oversight, budget, contractor, contracting, and test organizations. IPTs must be given budgetary and decision making authority. They must have authority to adapt requirements and set testing plans. To lend this authority and to set an example, personnel at the PEO level should be members of—and active participants in—at least the highest level IPT. Above this there may be a command wide "overarching" IPT. This group should focus on the risk management plans established in each lower level.

Provide Training

People need new skills to deal with EA and SD. These skills can come from post-secondary education, service-wide training, and training within specific projects. At the most personal level, the work groups recommended creation of a cadre of gurus to aid programs in adoption of EA and SD. In addition, various forms of written instructional material must be developed, including guidebooks and an insert on the definitions of EA and SD to accompany copies of DoDI 5000.2. At the educational level, modules on EA and SD need to be developed and incorporated into the curricula of Professional Military Education (PME) and the Defense Acquisition University (DAU).

Study SD and EA

SD and EA require further study in order to validate and improve the processes. Three separate work groups recommended producing documented case studies of EA and SD projects. There should also be studies of completed, non-EA projects to determine the degree to which EA would have improved the process. In addition to documenting projects, the work groups recommended conducting pilot studies to explore and validate the methods. These studies can incorporate innovations such as technology to continuously involve the user community. One arena for pilot studies should be the Simulation Based Acquisition Initiative (SBAI). Finally, the SD process needs to be enhanced with a catalog of risk patterns and suggested mitigation strategies.

In his opening charge to the conference, Dr. Steve Cross, Director of the SEI, asked three questions. (He suggested that the answers might be "no.") In summing up the work group presentations, Cross returned to these questions and found reasons for hope. He said

- Can we define EA?

    Yes, but we all need to educate our communities—advocacy needed

- Do we know how to do it?

    Some of us do, but we need to make it understandable and repeatable—need pilots, case studies, training, advisory services, etc.

- Will we do it?

    It is up to us to make change happen.

With this charge, attendees went forth to engage the world.

5 Work Group Reports

The five work groups were each assigned a specific topic:

Group "Definition": Canonical definition of EA

Group "Strategies": Successful strategies for EA

Group "Mapping": Mapping between SD and EA

Group "Barriers": Institutional barriers to EA and SD

Group "Operationalization": Practical steps to operationalize SD and EA

Work groups were asked to focus on producing "actionable recommendations":

- Who should do X?
- Who needs X? (That is, who should be/could be the customer and funder?)
- Why is it needed (rationale), what is the benefit?
- What is a reasonable time frame for accomplishment (and how much might it cost)?

Each work group was asked to cover the following aspects of its topic:

- A Vision Of Successful Spiral Development Practice
- Problem And Challenges Facing SDM
- Critical Success Factors To Success Of SDM
- Recommended Actions

5.1 Work Group "Definition": Canonical Definition of Evolutionary Acquisition

Panel: *Pat Place, SEI (Co-Chair); Don Reifer, CSE (Co-Chair); Clyde Ellis, Quantum Research; Iris Kameny, Rand; Jim Linnehan, Army; Jim Marple, SPC; Gary Thomas, Raytheon*

Work Group Purpose

The purpose of this working group was to define evolutionary acquisition in order to

- Foster a common understanding of evolutionary acquisition
- Bring clarity to policy documents
- Serve as a basis for promotion of the evolutionary acquisition method

The working group wanted to produce

- A crisp definition of evolutionary acquisition
- Standard terminology for evolutionary acquisition
- Characteristics of common DoD evolutionary acquisition variants and invariants

Deliberations

The group chose to tackle the issues of

- Confusion within 5000 documents over terms *evolutionary* and *incremental* acquisition approaches
- Lack of a characterization of the approaches that PEOs and PMs can relate to when reading the documents

Standard brainstorming was chosen as a working process, with the "right hand" rule of engagement: when two wished to speak, the turn passed to the right from the present speaker.

Our major conclusion was that we needed to expand the task to come up with standard definitions for both Evolutionary and Incremental Acquisition. We did so and came up with these definitions:

- Evolutionary Acquisition deploys core capability and incrementally inserts additional capabilities as requirements are refined.
- Incremental Acquisition deploys a full capability that is incrementally fielded based upon firm requirements for each block.

These definitions can be refined with invariants and variants. Here, an invariant is an approach that is invariably followed as part of the method, and a variant is a dimension along which the process can be varied while still following the model. The invariants and variants for the two acquisition models are listed and compared in Table 2.

Table 2:   Invariants and Variants for EA and IA

Evolutionary Acquisition	Incremental Acquisition
1. Multiple deployments accommodating evolving requirements Opportunistic technology insertion Many unknowns Evolving threats Users' understanding of *delivered* capabilities Related variants: Degree of flexibility; Degree of time phasing	**1. Requirements for multiple deployments are firmly defined** Planned technology insertion Few unknowns Defined threat Users' understanding of *final* capabilities Related variant: Degree of time phasing
2. Risk driven Increments defined to reduce risks Risks influence increment content Related variant: *Unknown* number of increments	**2. Requirements driven** Capabilities for each increment are *defined* Related variant: *Known* number of increments
3. Emphasis on total life cycle activities	
Can plan as you go	Preplanned
All life cycle activities must be planned for each increment	
Related variants: Testing, training, support, etc.	
4. Decision point at end of each increment involving appropriate stakeholders	
"Field" or "No Field" decision; "Am I Done" decision	
Related variants: List of appropriate stakeholders; Choice of decision making method (risk-based, funding, etc.)	

The resulting definitions differ from those offered by the February workshop in several ways. First, the invariants have been expanded by listing the characteristics of each. Second, two February invariants—concerning deployment and requirements—have been combined into Invariant 1 above. Third, Incremental Acquisition has been introduced and defined. Fourth, references to Anchor Point Milestones were removed because they apply during development rather than during acquisition. (Their place should be addressed by the Mapping work group.)

Recommendations

The group made the following recommendations. In order to be concrete, each specifies the office of primary responsibility ("agent") and a date by which the work can and should be accomplished.

- Use definitions to develop an insert that can be put into 5000 Directives, Regulations, and Instructions. Agent: SIS Office. Due date: 31 October 2000.

- Develop implementation guidance for existing publications, e.g., AFI 63-123. Agent: SIS Office. Due date: 30 April 2001.

- Develop guidebook for PMs and PEOs addressing "top 25" implementation questions. Agent: SIS Office. Due date: 30 April 2001.

- Document experiential case studies. Agent: SIS Office. Due date: 30 April 2001.

- Identify focal point in SIS Office for EA. Agent: SIS Office. Due date: 30 April 2001.

- Develop education and training modules for insertion into Acquisition Management courses. The appropriate level of detail is a two-hour module explaining use of EA and a four-hour module on case studies. Agent: DSMC. Due date: 1 September 2001.

5.2 Work Group "Strategies": Successful Strategies for Evolutionary Acquisition

Panel: *Lisa Brownsword, SEI (Co-chair); Caroline Graettinger, SEI (Co-chair); Robert Flowe, OSD/PA&E; Charles Leinbach, C-bridge; Bobby McKinnon, Army War College; Jeff Rothenberg, Rand*

Work Group Purpose

This purpose of this working group was to capture the participants' experiences in the use of evolutionary acquisition (EA) in order to

- provide guidelines
- collect successful strategies to aid others in successful use of EA

While the focus of the working group was EA, the participants were using spiral development (SD) as well. Due to work group time limitations, descriptions and conclusions are necessarily preliminary.

Participants

The work group participants included

- Lisa Brownsword, SEI, co-lead
- Robert Flowe, OSD/PA&E (cost analysis); previous experience with ESC and Air Intelligence Agency to implement a more efficient acquisition approach using spiral development; developed acquisition strategy for an ACAT III program
- Caroline Graettinger, SEI, co-lead
- Charles Leinbach, C-bridge; experience leading customers through EA process to support C-bridge SD process; worked with 40 e-business systems, $0.5-10M sized projects; authored large part of C-bridge's RAPID Value™ method
- Bobby McKinnon, Army War College (senior service fellow); previous experience as product manager for ACAT 1AM program; evolutionary and incremental acquisition program, C4I systems
- Jeff Rothenberg, Rand, doing study on EA

Working Definitions

While other groups were tasked to form operative definitions for EA and SD, this group found the need for a common frame of reference for strategy discussions:

> The focus of EA is to field a core capability quickly and then add capability based on user input and priorities over time. With EA, users don't know exactly what is needed in the system. EA requires some general notion of system scope and boundaries at the operational level (i.e., an operational architecture) before it is begun.

> SD is one development approach for satisfying the requirements for EA.

> SD and EA are separate processes but share some underlying characteristics, such as being risk-driven, architecture-focused, and engaging continuous user involvement.

Successful Strategies

The working group explored three EA/SD approaches. The experience of the group did not include embedded software systems.

5.2.1 Approach A: COTS + GOTS + Custom Software Development

Motivation for EA/SD

There was a lack of clarity in the overall requirements base, which motivated the use of evolutionary acquisition. Program participants knew they had funding limitations that argued for an incremental approach in those areas where the requirements were somewhat better defined.

Summary of Approach

This approach identified a fielded basic capability based on the input of the users and limited by available resources. The program created the infrastructure (for example, office automation, network, desktops) in the first increment. Use defined each new increment that was added in roughly six-month increments. Successive increments developed the applications that worked on the infrastructure fielded in the basic capability. Respected stakeholders participated so all their requirements were addressed. Maintaining user involvement through incentives was also a key factor.

Multiple contract vehicles, such as Indefinite Delivery Indefinitive Quantity (IDIQ), level of effort, and time and materials, were used to balance the risk between the government and the contractor. The core capability used an IDIQ contract. Integration and testing were done with a time and materials contract. Proposals identified labor categories and total hours for government comparison and negotiation with the contractor. The program used a fixed price contract to manage and develop the application capability where requirements were well known and implementation was low risk. The contract would limit total hours and was set up each year based on contractor input. Award fees were a useful device for increasing customer satisfaction.

Key Strategies

The following strategies were considered key in applying Approach A.
- Identify and field a basic capability that was defined based on user input within the context of available resources.
- Define the next increment of capability based on negotiation between users, developers, testers, etc.
- Add additional capability in increments of roughly six months.
- Use multiple contract vehicles to balance the risk between the government and the contractor (IDIQ, level of effort, time and materials).

- Use award fees to provide incentives for the contractor.
- Provide incentives for the user.

5.2.2 Approach B: C4I Program, ACAT III

Motivation for EA/SD

The members of this C4I program considered that the biggest risk was the anticipated major change in concept of operations. Therefore they chose an EA and SD approach that strove to include constant user involvement.

Summary of Approach

Work with stakeholders of all affected areas (including security and interoperability) to derive a wish-list of features. Prioritize the list in collaboration with the stakeholders and perform a risk analysis of each item to form a priority/risk matrix. Address high-priority requirements up front. While all high-priority items may not be incorporated into the first build, a program must begin allocating resources to address them from the beginning. High-risk items are explored through short duration prototypes that users then evaluate to better define the requirements. Prototypes are also used to explore technical feasibility of an implementation. Architecture constraints are identified concurrently with requirements elicitation/analysis.

Stakeholders and the program office allocate prioritized wish/requirements list items to upcoming increments. An overarching procurement and management plan is created that determines increments, including cost, schedule, and general functionality. Increment delivery schedules are based on how rapidly the user community incorporates the release into its operations.

A vital concern for program management is obtaining end-user involvement when users are trying to deliver on their own missions and retaining the involvement of experienced, knowledgeable users. This program was able to co-locate the acquisition group with end users or end-user surrogates. This includes funding for the involvement of the end users.

Day-to-day interactions are necessary so acquisition folks can absorb the requirements and priorities of the users. This also helps facilitate dialogue to help users understand the implications of what they are asking for and what their expectations ought to be. Setting the expectations of end users for any prototypes must be carefully managed. Feedback from users is well structured to minimize impact to their normal mission work.

Flexible contracting strategy is required to allow risk mitigation. A combination of contract vehicle types, such as time and materials or task orders, are vital, including the use of appropriate contractor incentives.

Key Strategies

- Users or user surrogates are critical. Make it important to them to participate. A program will need robust, high-bandwidth access to users.

- Be judicious about your release cycles; don't perturb the users with too frequent releases. Involve the users in planning for release cycles including training, rollout, data conversion, and organizational change impacts.

- Continuous engagement with the stakeholder community may drive system engineering and program management resource and skill requirements, so don't scrimp on staff. The program management staff must have greater skills than what is typical now.

- Use flexible contracting (time and materials, task orders, appropriate incentives) to allow risk mitigation.

- Address the high-priority items first, don't defer the high-risk items.

5.2.3 Approach C: e-Business Systems

Motivation for EA/SD

This is the standard acquisition and development approach this consulting firm uses to mentor other programs in developing e-business systems.

Summary of Approach

The acquisition process starts with a planning phase that explicitly defines objectives.

A Visioning Session, involving the major stakeholders—and especially end users—is held to help develop a preliminary list of features. In parallel, the business value (economics) of the project is translated into budget estimates and a plan for spirals in the project development. A priority/risk matrix is created describing what the program should be doing to meet its strategy. As the project proceeds, risks are revisited. The preliminary architecture is designed by the end of the planning phase. A key element of the architecture is its growth capacity across increments.

The next phase is the first EA increment that results in an increment delivery. Every increment's goal should be delivery into real-world environments. The infrastructure needed by the end user is delivered in the earliest increments. The first release incorporates tasks from the ends of the list: the easiest because they can be done and the hardest in order to mitigate the risks they pose. Management of configurations and changes is required from the outset of the project. The configuration and change control process must be well defined and efficiently practiced. Weekly meetings to look at the artifacts of the projects and new risks are also required. In early increments, development changes are relatively easy to make and require low-level approval authority. In later increments, higher levels of approval are required.

Key Lessons

- As part of the project preparation, educate the customer, the user, and the contractor on the EA approach.
- Goal of every EA increment should be delivery into a real-world environment.
- In the first increment, put into place the infrastructure that the end user and the development team will need.
- Create a very well defined configuration and change control process at the outset.
- Design the primary architecture by the end of planning phase.
- Make sure there is a strong chief technical architect in the program office.
- At the project outset, define the goals of the project with active user involvement.

5.2.4 Strategy Summary from All Approaches

From the three EA/SD approaches that the working group explored, the following essential tactics were extracted:

- Develop an acquisition strategy that allows you to address high-risk, high-value areas first. Don't defer high-risk elements to the end. Start allocating resources towards high-risk elements.
- Build something that is fielded and usable at every increment that includes adequate documentation, training, and support.
- Balance risks between stakeholders through a team environment that shares risks and tools.
- Develop incentives for stakeholders to remain engaged.
- Make sure you understand the motivations of each stakeholder group.
- Avoid mandating a single life-cycle model - one size does not fit all.
- Contract vehicles are important tools in flexibility. Allow the use of all contract vehicle types, where applicable (e.g., fixed price, time/materials).
- Provide appropriate incentives for all stakeholders.
- Hold people and organizations accountable.

Maintaining management involvement is key. EA is not a license to abdicate responsibilities. Maintain management involvement through frequent reviews that involve all stakeholders.

Recommendations for Further Work

The working group's personal experience does not comprise a statistically significant sample. As a result, we recommend

- Development and dissemination of detailed case studies of EA and SD. Potentially this work could be done through the sponsorship of C3I and AT&L.

Group members found from their collective experience that creating and sustaining the participation of relevant stakeholder communities, in particular end users, was foundational for

successful EA and SD approaches, but there are limited codified practices. Thus, we also strongly recommend that the DoD

- Identify and prototype effective practices and supporting technologies that facilitate the sustained engagement of the stakeholder communities, and especially end users.

Lastly, we recommend

- Development of a cadre of industry and government people knowledgeable in the pragmatic application of EA and SD who are readily available to program offices and contractors.

5.3 Work Group "Mapping": Mapping Between Spiral Development and Evolutionary Acquisition

Panel: *Elliot Axelband, USC (Co-Chair); David Carney, SEI (Co-Chair); Brad Clark, SEI; Kevin Forsberg, CSM; Elwyn Harris, Rand; Katy Smith, MITRE*

This group was chartered to consider the relationship between spiral development (SD) and evolutionary acquisition (EA). This section generally follows the attached viewgraphs that were used to summarize the group's conclusions. These were presented on the final day of the workshop.

A framework was developed during the workshop that provides the context of this section and which is essential to understanding it.

Framework

The context of the workshop was software intensive systems. The natural question then is what is a software intensive system? While the "Definition" Work Group formally addressed this question during its working session, the framework was established by the workshop as a whole, prior to the convening of the work groups and their subsequent reports.

The discussion was driven by asking whether the newly planned Navy surface combatant DD-21, the multi-service next fighter aircraft – JSF (Joint Strike Fighter), and the Army's next combat vehicle – FSCV (Future Scout Combat Vehicle), were examples of software intensive systems. By a show of hands, the vote was almost unanimous that they were. This led to the conclusion that software intensive systems were really, in most cases, hardware, people, and software intensive, a viewpoint that must be retained in considering the conclusions of this and other working groups.

There are exceptions to this. These are systems that are only housed in hardware (computers) and are otherwise pure software. These go under various guises: C4ISR systems, information systems, and software-only systems. Such systems, however, though an important class, have very different properties than the more general class of systems combining hardware, software, and people that are considered under the term *software intensive systems*. One other term of art used by one member of the C4ISR community was to call non-C4ISR systems by the term "iron systems" which was his way of attaching a distinctive label to the more general class of software intensive systems.

The question of whether the term software intensive systems included hardware, people, and software intensive systems such as JSF, DD–21, and FSCV was also addressed independently on the last day of the conference by Dr. Jack Ferguson of the DoD. He stated that they were included, confirming the interpretation taken by the workshop as a whole.

A distinction of note was the composition of the workshop—only about 5% of those present were from industry. The conference was government- (including FFRDCs) and university-dominated. It was generally agreed that such a skewed composition would not constitute a good IPT and would be remedied at future related events.

A disagreement of note between the conclusions of this working group and the "Barriers" working group concerns the existence of legal barriers to the incorporation of spiral processes within evolutionary acquisition. The "Barriers" working group reported at the workshop that here are none. This working group, however, believes that under existing DoD policy, software intensive systems that contain hardware must undergo a design freeze prior to the start of manufacture and so must suspend spiral processes for the production lot under manufacture. Evolutionary acquisition does not preclude this; nor should it, given the capital intensive nature of manufacturing. An independent inquiry subsequent to this workshop confirmed the existence of that DoD policy.

Summary

Evolutionary acquisition as embodied in the current versions of draft DoD 5000.1 and 5000.2 are strongly supported. They are an incremental improvement to their predecessor documents and incorporate changes that hold the promise of improving the acquisition process.

Spiral development processes have the potential to enhance evolutionary acquisition as an implementing procedure provided they are incorporated properly and with due consideration of both their strengths and weaknesses for the applications being considered. Software only systems and (hardware and people) software intensive systems are very different in their nature and must be treated as two separate cases. Procedures that proved successful in one case should not automatically be presumed to be successful in the other.

Policies regarding the incorporation of spiral development should evolve from interaction among the players in a fully representative IPT. Government, universities, and industry should all be represented.

Policies should not be imposed by fiat or on the basis of anecdotal evidence. The use of studies, test cases, and prototypes is advocated to establish a minimally intrusive body of evidence to serve as basis for policy. More generally, policy makers are urged to lead by example, and not fiat, where possible.

Within government there are numerous established policies and instituted behaviors that are antithetical to spiral processes and which must be addressed. Many of these have been encountered as factors that have limited the success realized by acquisition streamlining these past five years. They include (1) rapid rotation of assignments of military acquisition officers, (2) program cancellation as a mark of failure, and (3) the government contracting community's aversion to risk-type contracts. These are discussed more extensively in the body of the section.

Further, there is not a common understanding of the flexibility inherent in waterfall, V, Synchro X, and other models of development processes and in the properties of production processes. This limits the potential for success that will be achieved in incorporating spiral processes. Further interaction and improved IPTs will provide the common understanding that will accelerate the well-thought-out introduction of spiral development into evolutionary acquisition.

Mission

This working group was chartered to understand the interaction between spiral development and evolutionary acquisition in order to clarify the various government and contractor roles.

Vision of 2010

In an ideal world in the year 2010 the acquisition community would be well trained in evolutionary acquisition and the array of strategies—including spiral development—to implement it. Strategies would be employed as a function of the nature of the program under consideration drawing upon the broad experience gained in past applications. Strategists would have a good understanding of the complementary as well as contrasting nature of various strategies in order to make well-considered decisions. Such understanding will include the facts that spiral development is not incompatible with waterfall processes, and that spiral development is incompatible with the fixed price contracting approach that is required for any one production lot.

Congress, the DoD, the services, and industry would understand that acquisition strategy must be tailored to the nature of the program to which it is applied; they would be generally supportive of this approach and of evolutionary acquisition. All participating parties would be incentivized to take a tailored evolutionary acquisition approach and would be rewarded upon success in the form of professional advancement and—for industry—incentive fees. Metrics would be clearly established to provide the basis of evaluating performance, including schedule, cost, performance, technology insertion, international cooperation, standardization, and risk reduction, as appropriate. It would be recognized that program cancellation is a reasonable occurrence when undertaking high-risk programs, and rewards would be provided for the correct early determination that cancellation is the proper action.

The DoD's processes related to evolutionary acquisition would be supportive. Program managers would be long tenured so that they can gain experience throughout the considerable program length some programs would require. DoD program managers would be rewarded for program cancellation when that is a proper decision in the interest of the DoD. Contracting officers would be prepared to offer and endorse flexible contracting methods when these are required to implement spiral development.

Congress would recognize the need to stabilize the defense budget and this in turn will provide a stable level of employment for defense professionals that will enhance their ability to learn and apply successful evolutionary acquisition techniques.

Two Types of Systems

Key to the success of evolutionary acquisition and the use of spiral development as an implementing tool is the ability to distinguish between two very different types of systems that are covered under the rubric of *software intensive systems*. By software intensive systems (called by some "iron systems"), we generally mean those that have significant hardware and people content. By information systems (called by some C4ISR systems) we mean those where the hardware is generally a commercial off-the shelf/Government off-the-shelf (COTS/GOTS) computer, housing software that is the essence of the system.

Information systems have no production phase in their development, can be relatively easily changed after deployment by the use of patches, and can have great synergy with commercial software developments.

Software intensive systems, by contrast, have a long production cycle, are relatively difficult to change after deployment, and have less synergy, except perhaps at the electronic component level.

These differences are profound and must be regarded with care. Nonetheless, increased use of spiral development can enhance evolutionary acquisition in both cases.

Anticipated Difficulties

In the year 2010, evolutionary acquisition enhanced by spiral development will have a greater degree of concurrent research and development, production, and operation for a given program than occurs today. There will also be a more rapid change cycle. While these are desirable outcomes that derive from evolutionary acquisition and spiral development, certain difficulties will be encountered during implementation and they must be anticipated and included in program planning. These are as follows.

- increased simultaneous use of colors of money, and ambiguity in the proper application of colors of money
- a greater coupling with the annual budget cycle
- more resources to understand end-user feedback
- a greater need for upward and downward compatibility of deployed systems
- a greater acceptance of risk and tolerance for failure by the acquisition community
- an increased need for frequent all-player program reviews and the funds to support them

Recommendations

We recommend the following steps to work toward the improvement and adoption of evolutionary acquisition:

- Convene an IPT to further the incorporation of SD within EA. In addition to DoD personnel, membership should include representatives from industry, INCOSE, and PMI

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who will involve their home organizations in furthering the work (Ferguson, with support from Boehm, Foreman, and Axelband).

- Explore EA further prior to imposing it as a policy. Evaluate how current programs would have fared under EA. Conduct a prototype study (Etter with SAEs).

- Plan each EA/SD project so consecutive spiral cycles converge toward a final goal. These plans must be cognizant of—and resilient to—program re-direction, technology change, and other inevitable sources of distraction. Among suitable techniques are the use of anchor points advocated by Boehm and stable intermediate points as advocated by Rechtin [Boehm 00, Rechtin 00 p. 99].

- Depict EA so as to reveal the feedback possibilities instead of making it appear as a rigid linear approach. The depiction of waterfall-like processes as being spiral-cycle free is inaccurate and misleading. It builds barriers to understanding the full tool kit that the EA/SD practitioner can use.

- Avoid SD for the manufacture of any lot in programs with production phases. Production programs are fixed price and use strict earned value tracking, both of which are incompatible with SD.

- In applying EA/SD, distinguish between information systems and software intensive systems.

5.4 Work Group "Barriers": Institutional Barriers to Evolutionary Acquisition and Spiral Development

Panel: *Ceci Albert, SEI (Co-chair); Fred Hansen, SEI (Co-chair); Tom Bostelaar, TRW; Dave Durfee, TASC; Scott Henninger, U. Neb; KC King, SAIC; Stan Levine, DSCOPS-FD; Warren Morrison, SEI*

Summary of Discussion

This work group determined that there are *no* legal, policy or regulatory barriers to EA/SD. (After all, there are programs that have successfully applied these concepts.) The group firmly believes that program managers already have the latitude to implement EA/SD—if the program manager sees EA/SD as a solution to the program's needs. Each program manager must select the most appropriate approach to address unique program risks. In order to be successful in selecting the right approach, the program managers must understand the available alternatives and the implications of each alternative. However, the culture (the overseers, the program support activities, the staffs) must change to accept and implement the program manager's chosen approach.

On the other hand, the group was concerned that the amount of information a program manager would need to know to successfully select and implement an EA/SD approach might be more than could be expected of a "typical" program manager. The program manager must be able to

- write time-phased requirements that meet cost targets by increment
- define the architecture up-front (before all the requirements are defined)
- maintain credibility and support for a program with flexible requirements, requiring flexible contract vehicles and funding strategies
- develop the analytic basis to set up the program
- know the program risk patterns and the models they generate and which need EA/SD
- negotiate appropriate user interfaces in an environment that demands active stakeholder negotiation of flexible requirements
- decide what is good enough and when to stop development
- develop metrics and incentives that support EA/SD implementation in support of program goals.

The group discussed different types of risk patterns that must be accommodated by acquisition and development approaches. For example, a weapon system (such as a tank) requires a huge capital investment in hardware and manufacturing capability to produce, and the requirements are relatively easy to bound. A software system (such as a command and control system), however, is intrinsically linked to the demands of its users; therefore, the system is linked to its user interface. The requirements for a software system are harder to determine at any point of time than a weapon system's requirements, and the concept of operation is constantly changing across the life of the system. In the case of software systems, physical pro-

totypes are easier to build than an activity model of the system. In many cases, requirements can be characterized as "I'll know it when I see it" (IKIWISI).

Because of the experience of the group members, the group concentrated on command and control type software systems.

Vision

For 2010, the work group envisions an environment where
- each project follows the process model best suited to its unique risks
- different patterns of behavior are followed based on an understanding of the program's unique pattern of risks
- services are able to acquire the capabilities they need in an era of diminishing funds

In order to realize this vision, program managers, their staffs, their contracting partners, and the end users must be trained, skilled, experienced, and accepting of risk and innovation; there must be a high level of trust and cooperation among all stakeholders (end users, business process owners, acquirers, developers, integrators, vendors, testers, etc).

Barriers

Having determined that there are no formal legal or policy barriers, the group identified four major categories of impediments to implementing EA/SD. The group characterized some of the issues associated with each category and then developed specific recommendations aimed at addressing those issues.

The first category is *risk aversion*. This category includes the failure to use risk to drive the acquisition and development processes as well as program management; the failure to find and identify the real program risks; and the perceived end-user risk of receiving a first increment that has less capability than the legacy system it replaces. Three recommendations were made in this category:
- Senior leadership (PEO and comparable end-user representative) should demonstrate support for EA/SD through participation in spiral development integrated product teams (SDIPT).
- The overarching integrated product team (OIPT) should focus program oversight on the program manager's risk mitigation plans in preference to the program's past history or current status.
- The PEO should make risk mitigation funding both acceptable and available.

The second category is *budget and contracting processes*. The group is concerned that EA/SD are not synchronized with the budget process; that current contractual procedures are not sufficiently flexible (contracts do not support loosely defined efforts and do not support close technical working relationships between government and contractors); and that contractors are reluctant to partner with competitors (there is little incentive for a contractor to share information or products with companies who are or may be competitors). Three recommendations were made in this category with respect to budget:

- OSD should develop mechanisms to synchronize funding decisions with anchor point milestones. Date: concurrent with the release of 5000.2R.

- OSD should support the Services in budgeting C2 programs in the aggregate (at the PEO level) to enable funding of spirals on a realistic and timely basis. Date: start with the '02 Budget Estimate Submission (BES).

- OSD and the Services should promote an understanding of the unique funding needs of the EA/SD programs by the financial management community (to avoid cuts of funds essential to implementation of flexible requirements and milestones). Date: concurrent with release of 5000.2R.

Two recommendations were made in this category with respect to contracting:

- The Defense Contract Management Agency should develop contracting models and suggest incentives that match EA/SD models. Date: September '01.

- Program managers should include requirements and incentives for sharing information and products in all appropriate contracts.

The third category is *inappropriate stakeholder participation*. The issues in this category include user organizations being unwilling to offer proactive participants (representatives that are not empowered, not involved enough, unwilling to negotiate requirements, or don't know what is needed); the test community being unready to partner in the development process (don't know how to apply their charter in an EA/SD environment and spiral developers no knowing how to incorporate testing); IPT participants not being empowered to make decisions (including testers, users, funders, acquirers, contractors as participants, requirements and risks as decisions). Four recommendations were made in this category:

- OSD should update IPT language to include a broader definition of "stakeholder" for spiral development projects. This definition should include oversight, budget, contractor(s), contracting, and test organizations.

- Program budgets must include funding for participation of stakeholders in program activities.

- The number of IPTs that require end-user support must be limited so members can be empowered and knowledgeable.

- IPTs should be given the authority to negotiate requirements, test strategy, and budget allocations.

The fourth category is *lack of training and education*. The group was concerned that there is no EA/SD doctrine. Such a doctrine has to include when to use EA/SD, terminology that is specific to the processes, and training manuals. DoD 5000 and AFI 63-123, which mandate use of EA and SD respectively, are not doctrine but policy. There is no resource that provides a clear understanding of EA/SD—though we believe the Air Force manuals are a start at this. In addition, there is a lack of institutional training and education in EA/SD. Program managers do not have an understanding that there is enough flexibility to adopt appropriate process models and there is no easily accessible source or proponent for EA/SD to support program managers. There is little information on EA/SD in courses provided to military and government civilian employees. Specifically, formal educational programs fail to provide education on risk patterns. Five recommendations were made in this category:

- FFRDCs should be asked to develop representative risk patterns and their associated mitigation process models to show which patterns are best suited to EA/SD. (The SEI risk mitigation database is a good starting point). Date: Feb '01.
- The Services should validate EA/SD models through industry and government pilot projects as part of the Simulation Based Acquisition Initiative. Date: September '01.
- The SEI should be tasked to produce a case study/examples document. Date: September '01.
- The OSD should require EA/SD curricula be incorporated in Professional Military Education (PME) and Defense Acquisition University (DAU) for stakeholders as well as acquisition professionals. Suggested components are listed below. Date: February '02.
- The OSD should provide a contract vehicle for EA/SD facilitators and mentors to support early adopters of EA/SD.

In thinking about training, the group came up with some recommendations as to what should be covered in a curriculum. The group felt that the following information should be provided to PEOs:

- invariants/variants
- case histories (including EMD and Deployments phases)
- risk management (doing the hard things first)

The group felt that potential PMs should be sent to DARPA or NASA in order to participate in transition of technologies key to their programs.

The course for end-users should cover

- the role of negotiation and flexible requirements
- how the ORD affects program decisions, including upgrade plans
- what to expect/demand from executable prototypes
- demonstration of program risk patterns
- expectations from model based software engineering (i.e., MBASE)

Summary

It is the group's fervent hope, if not actual belief, that following our recommendations in the areas of

- risk aversion
- budget and contracting processes
- inappropriate stakeholder participation
- lack of training and education

will help achieve our vision for acquisition in 2010. That is, one where projects always follow appropriate process models, base their behavior on a full understanding of the risks, and acquire needed capabilities sooner and at lower cost.

5.5 Work Group "Operationalization": Practical Steps Necessary to Operationalize Spiral Development and Evolutionary Acquisition

Panel: *Joseph Ferrara (co-chair Georgetown University), Eileen Forrester (co-chair, SEI), Thomas Bono (MITRE), Mike Bloom (MITRE), Ed Cameron (US Army), Peter Hantos (Xerox), Cheryl Jones (US Army TACOM), Tony Jordano (SAIC), Larry McKee (MITRE), John Miller (TRW), Calvin Young (Quantum Research International)*

Work Group 5 considered what steps the Department of Defense (DoD) should take to operationalize and ultimately institutionalize evolutionary acquisition and spiral development (EA/SD). Its objective was to be practical and realistic, and wherever possible, avoid recommendations that aimed for the quick fix and ignored the practical realities of change management in large, complex organizations.

Guiding Principles

The group discussion was guided by a few broad principles. First, the group did not assume that EA and SD were necessarily always the most appropriate strategy and tool. Rather, as the DoD's new 5000 policy documents say, the group's basic assumption was that the success of a DoD program is fundamentally dependent on crafting an acquisition strategy that is responsive to that program's unique blend of characteristics. In other words, successful operationalization of EA/SD requires support for selecting the right life-cycle model for the circumstances; EA/SD may be it, and we should ensure that EA is selected when it is the best match. EA/SD is not a silver bullet.

A second guiding principle was the notion that not all stakeholders are created equal. That is, for any given change management initiative (in this case, EA/SD), one can define a set of critical stakeholders whose early adoption is vital to ultimate success because it attracts other followers and brings them along as the organization moves toward institutionalization. We noted that EA/SD has a large number of potential stakeholders and we endeavored to focus on the most important for operationalization of EA.

Third, the group was struck by the need for the champions of EA/SD to tell a consistent story. As was noted several times during the workshop, DoD spokespersons have not always been clear in elucidating the basic building blocks of the EA/SD approach. (In part, this is due to the messiness of the policy development process and the inevitable need to make compromises along the way. But now that the new 5000 policies have been formally signed out, it is very important that DoD begin to speak with one voice.) We recognize the need for consistent communication from the various sponsors and champions of a change to appropriate use of EA.

Next, the group felt the proper scope of its task was to focus not on individual organizations (say, the Army, or the Naval Air Systems Command), but rather on the broader defense acquisition community. Operationalization is a community-wide enterprise that will require buy-in, collaboration, and cooperation from a diverse set of contributors.

A final guiding principle was the recognition that institutionalization of EA/SD will require a whole product – not just piece parts – and, moreover, that this product will require systematic leadership attention and interdisciplinary collaboration.

Summary of Discussion

To make the most of the brief time allotted, the group quickly identified the key issues its members felt were most important to success. This had two advantages – it gave the group an opportunity at the outset to brainstorm a number of possible solutions, and then to organize these solutions into coherent sets of transition mechanisms. Next, the group identified– and prioritized–the stakeholders important to institutionalization. After this, the group mapped the various transition mechanisms along a path representing the phases of organizational commitment, stretching from initial contact to full institutionalization [Conner 83]. Finally, the group made a top-level recommendation about the need for a full-time steward to guide transition and adoption.

It is important to note two things the working group did not do. First, it avoided a recitation of familiar litanies. The sense of the group was that litanies,[1] by their very nature, tend to be trite and to induce a certain numbness in the listener, and so the group avoided them (with some, but not total, success). Second, the working group did not attempt to draft a comprehensive plan for operationalization. Such a goal–even if the group had adopted it – would have been precluded by the severe time constraints in any event, but the group also recognized that its purpose was to point a way for others to follow, not to write the detailed blueprint.

Stakeholder Communities

Who are the relevant stakeholder communities? The group identified three main categories: (1) Program Management and Delivery, (2) Program Support, and (3) Policy and Oversight. See Table 3.

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[1] A good example of a litany is the oft-heard argument that "if only Congress would not micromanage," then all things would be better. This may be true but it is also utterly impractical and unrealistic.

Table 3:   EA/SD Stakeholder Communities

Category	Population	Comments
Program Management and Delivery	Program Managers (in government and industry) Members of the Program Office staff Contracting Officers Program Executive Officers Designated Acquisition Commanders Chief Engineers and Architects	This is the group most directly responsible for program success: for meeting the bottom-line goals of cost, schedule, and performance.
Program Support .	Logisticians Trainers and Educators Operators Requirements Writers Testers Scientists and Technologists	This group supports program management in the broadest sense: everything from writing the requirements from which programs originally flow to providing training and education.
Policy and Oversight	Congress Acquisition Executives and Milestone Decision Authorities Overarching IPTs Acquisition Reformers Auditors Budget Officers and Programmers	This group writes policy and provides oversight: both of individual programs on a case-by-case basis and of policy compliance in general.

After discussing the roles and responsibilities of these various stakeholders, the work group decided that the Program Management and Delivery community was by far the most important to focus on in developing a plan for organizational commitment and institutionalization. This decision bears some elaboration. First, this choice does not imply that the other stakeholder communities are somehow unimportant. They are very important; however, we cannot do everything at once. Because fundamentally, EA/SD is about program strategies, it makes sense to focus on the community most directly responsible for program success. Second, in a sense, the policy and oversight community is already committed to EA/SD, having just issued the new 5000 policies. And so constructing an elaborate program to convince this community of the merits of EA/SD would seem to be superfluous, a classic case of preaching to the choir. Third and most importantly, this choice reflects the work group's desire to be practical and realistic. As one workshop participant put it, to be truly successful, EA/SD "must get into the very DNA of program managers." If those responsible for program management and delivery don't adopt EA/SD, it doesn't matter if the others do—operationalization will fail.

A Phased Approach

The core of the work group's strategy for operationalization is a phased implementation approach in which adopters of the EA/SD policy are addressed in a meaningful, practical se-

quence. This approach offers several advantages. It flows from the finding that certain stakeholder communities are more critical than others to ultimate success and that such early adopters can play a catalytic role in organizational change. In addition, a phased approach recognizes that people accept change in fairly predictable patterns. Rarely do people (much less whole organizations) fall head over heels in love with a new technology and realize instantaneously how to put it into practice. Typically, it is not love at first sight but rather more akin to a gradual courtship where people learn more about the new initiative, overcome their fears and initial resistance, and begin to understand its real benefits.

In this vein, the work group based its approach on research from the training and development literature that posits a phased commitment to organizational change over time, a commitment that grows in intensity as the organization moves from basic awareness to actual use and demonstration of the new concepts. A graphic representation of this phased commitment path, with relevant mechanisms for adopting EA/SD, is depicted in Figure 9.
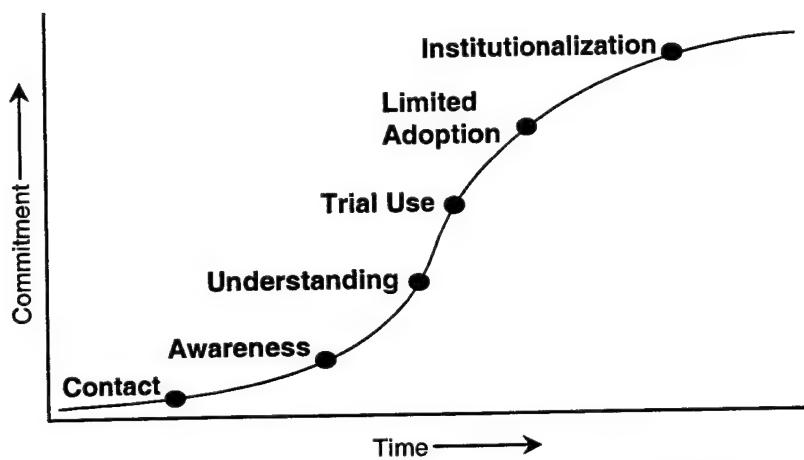
Figure 9: How Organizations Commit to Change

Table 4 below briefly elaborates on each of the stages of organizational change process.

Table 4: Stages of the Organizational Change Process

Stage Objectives	Example Mechanisms
Contact and Awareness	
Intended adopters recognize the name	Elevator speech
	Magazine articles
Basic grasp of what the new technology is and what benefits it offers	Web site with FAQs, illustrative success stories, points of contact, etc.
	Standard explanatory briefings for delivery at professional conferences
Understanding	
Deeper comprehension of new initiative and its essential tenets and techniques	One-day seminars
	Technical briefings
	More detailed case studies and success stories
More investment by adopters of time, effort, or other resources that will lead to a decision to try it out	Road shows (including program managers)
	Updating existing course content at DoD school houses to reflect new initiative
Trial Use	
Gradual organizational experimentation with new approach to demonstrate its value and learn lessons for future improvement	Carefully selected lead programs
	Commitment to support lead programs and document lessons learned
Enough information to make an adoption decision	Establishment of a senior group dedicated to supporting and nurturing lead programs
	Development of longer, more detailed course offerings
Word of mouth on results or other references	Documentation of barriers to adoption and strategies to overcome these barriers
Adoption	
Transition beyond trial use to a more mature organizational adoption of the new approach, including policy refinement and comprehensive education and training	Establishment of a robust set of organizational incentives, rewards, and consequences
	Refining policy and procedural guidance to reflect lessons learned through trial use
Information on costs and benefits plus other lessons in trial use	Development of a full suite of in-process aids and tools, including sample implementation plans, guidebooks, team coaching services, etc.
Preparation for rollout to common practice	Leadership attention to and resolution of lingering adoption issues
Institutionalization	
Full inculcation of the new approach into the culture and norms of the organization	A fully realized educational curriculum
	A systematic program of orientation and training for new employees as they enter the organization
Refreshment and upkeep	Stability of leadership commitment
Reinforcement and adaptation	Continuous improvement of adoption artifacts

An Overarching Recommendation

How exactly is DoD to initiate the actions described above? Who will take the lead and keep things on track? Who will ensure that the necessary actions–small and large–are tasked and accomplished? The work group felt that this was the most severe and pressing challenge facing advocates of EA/SD. There are government warehouses filled to bursting with new policy documents, sparkling briefings and guidebooks, and transition plans of all make and manner. But all of these products will not ensure success without consistent, systematic leadership. A major concern of the work group was that the nature of DoD bureaucracy, particularly the policy and oversight stakeholder community, is to declare victory and move on to new challenges after a new policy is published. In this scenario, implementation and institutionalization too often become mere afterthoughts. But of course the publication of a new policy is really just the beginning.

This is the animating principle that runs through the work group discussion laid out above. The publication of the new 5000–far from the end of a long road of policy development–is in fact only the beginning of the organizational change process. As we have argued, this process must be planned, managed, and measured and must focus on first things first. But someone must move things along. Who should that be?

It was the work group's strong recommendation that

- DoD appoint and fund an organization to serve as steward for ensuring the transition and adoption of EA/SD.

It is desirable that this organization be well positioned to deal with the full range of stakeholder communities, including government, industry, and academia. Moreover, it should be an organization that possesses demonstrable expertise in transitioning new technologies and practices to widespread use and adoption. It must also be perceived as being relatively neutral and objective. Consideration of these desired characteristics very quickly focused the group on Federally Funded Research and Development Centers (FFRDCs). It is part and parcel of the FFRDC mission to assist the government sponsor in building bridges to industry and academia. In particular, the work group strongly believed that the SEI, because of its FFRDC status and even more importantly because of its technology transition mission, is a logical candidate to serve as the EA/SD steward.

This recommendation has several advantages. First and most importantly, it ensures that rollout and implementation of EA/SD does not become a bureaucratic afterthought. As noted above, the publication of the new 5000 marks the beginning, not the end, of a long process. Second, appointing a steward is practical and realistic, and helps government leaders do their jobs. The leadership of the DoD acquisition community is busy and often spread far too thin. Having a steward to promote policy transition and adoption helps everybody. Third, a steward can reach out to all affected communities and map the complex interactions necessary for successful adoption. A clear finding of the workshop was that institutionalizing EA/SD would require numerous actions across a range of communities and disciplines.

To make this happen, the work group recommends that the SEI meet with its DoD sponsors as soon as possible to brief the results of the EA/SD workshop and to recommend the appointment of SEI as EA/SD steward. Key offices to be consulted include the Deputy Under Secretary for Science and Technology (sponsor of the SEI), the Director of Acquisition Resources and Analysis, the Deputy Under Secretary of Defense for Acquisition Reform, and the Service Acquisition Executives.

6 Conclusions

Evolutionary acquisition (EA) and spiral development (SD) are the current DoD effort to define an acquisition process that consistently attains that uncomfortably small apex on the pyramid joining low cost, rapid delivery, and high quality. Guarding the apex are arrayed the forces of nature, as shown in Figure 10.
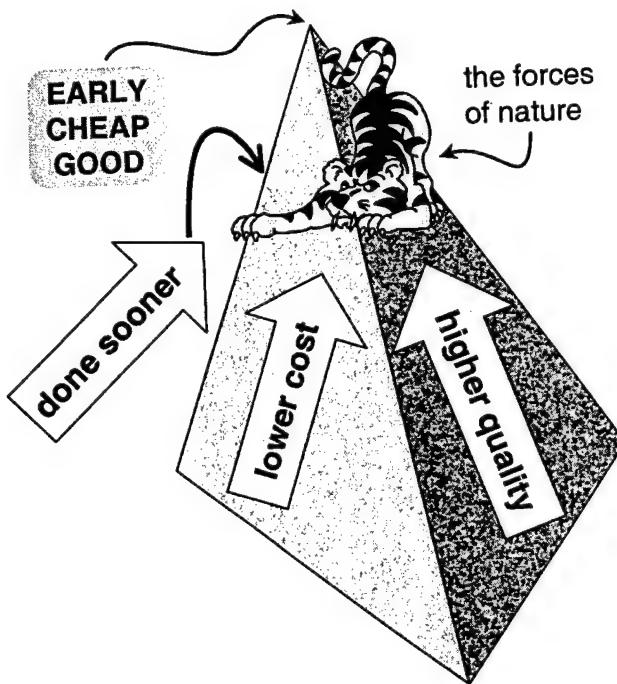
Figure 10: The Forces of Nature Guard the Apex of Process Achievement

There was no dissent at either the February or the September workshop to the notion that EA/SD can help attain the apex more often than other process models. Attendees were generally enthusiastic about the prospects. Nevertheless, the presentations and (especially) the recommendations can be read as leading to this cynical interpretation:

> We don't understand EA and SD
>
> and we aren't convinced they work,
>
> but we want them anyway so here's how to
>
> improve them, adapt the DoD, make teams work, and
>
> ensure their use.

Let us consider each phrase in turn, examining its roots and the reasons for hope.

We don't understand EA and SD

The notion that EA and SD are not well understood could be garnered from the fact that their definitions were one of the themes of the February presentations and the subject of work groups at both workshops. In fact, the work group sessions were intended to sharpen the definitions rather than to create new ones. The February work group did formulate four recommendations about further sharpening the definition, but the September group only formulated recommendations calling for further promulgation of the definitions.

Largely, the lack of September recommendations reflects the existence of definitions that came into being between the workshops. The definitions of evolutionary acquisition are given in Section 3.1. Spiral development is defined in a recent paper [Boehm 00, Boehm 01] as follows:

> The spiral development model is a *risk*-driven **process model generator**. It is used to guide multi-stakeholder concurrent engineering of software-intensive systems. It has two main distinguishing features. One is a **cyclic** approach for incrementally growing a system's degree of definition and implementation while decreasing its degree of risk. The other is a set of **anchor point milestones** for ensuring stakeholder commitment to feasible and mutually satisfactory system solutions.

The papers go on to sharpen the definitions by defining the highlighted terms and describing "invariant" properties of spiral processes together with allowable "variants" for each.

One mistake common among development practitioners is to confuse spiral development with any other method where the product is developed in a cyclic sequence of efforts rather than one single waterfall. Usually such efforts are conducted without risk management reviews and re-direction of the project at the beginning of each cycle. One example of this sort of confusion is the phrase in DoDI 5000.2 where it calls for an "iterative spiral approach" for development. Does this mean that there are spiral approaches that are not iterative? Or does it try to clarify the meaning of "spiral approach" by equating it with an iterative approach? There is no way to tell. The first is slightly incorrect insomuch as a first iteration risk analysis may determine that only a single iteration is needed. The second is more incorrect in that there are many iterative process models that are not spiral processes.

Other cases where iterative was equated with spiral occurred in the February presentations, but not in those of September. These instances of confusion probably reflect a deep-seated misunderstanding which will require much education to reverse. (Perhaps it would be useful to create a new name for the risk-based spiral method rather than try to re-educate everyone on the meaning of "spiral development.")

and we aren't convinced EA and SD work

The work groups suggest an uncertainty with the validity of SD and EA by asking for various kinds of demonstrations. These were the subject of at least 10 recommendations by 6 differ-

ent work groups. Typically these recommendations called for case studies, experimental validation, pilot projects, and return-on-investment or business case analyses.

In point of fact, workshop participants were themselves convinced as to the merits of SD and EA. The spate of recommendations was intended to provide the sort of concrete evidence that is the best argument to present to skeptical and unwilling potential adopters. Without a strong body of evidence, no amount of regulations and documentation can break a large, long-lived system free from the clutches of time-blessed procedures.

Little has been accomplished on the building of convincing evidence for EA and SD since the time of the first workshop in February. It is possible this goal will be accomplished by the recently funded Center for Empirically Based Software Engineering [CeBASE 01] or some other group utilizing the resources of the SEI Software Engineering Information Repository [SEIR 01].

but here's how to improve EA and SD

Although participants generally agreed that EA and SD were valuable techniques, they had suggestions for improvement in several directions. On the "people" dimension, these suggestions ranged from working to understand the human behavioral and cultural aspect down to the practical task of devising methods to encourage the identification and revelation of risks. On the "process" dimension, suggestions included development of tools, testing practices, and project assessment methodologies. One particular suggestion called for a catalog of risk patterns and the corresponding appropriate process pattern. At least two of the presentations described such catalogs in commercial use (Kitaoka in February and Jordano in September). These suggestions were all aimed at making EA and SD easier to use and thus more attractive for future projects.

here's how to adapt DoD to EA and SD

Given that EA and SD are seen as attractive strategies, and given the fact that no other strategies have been particularly successful, workshop participants determined that the DoD should encourage these policies. However, many factors in existing DoD policies, practices, and ingrained culture were seen as deterrents to the successful adoption of EA and SD. It is no wonder then, that the work groups proposed a number of changes for the DoD. These changes have been detailed in the work group reports and summarized under the categories:

- **Improve Contract Models**
- **Revise Funding Approaches**
- **Adapt Acquisition Policies**

Noteworthy recommendations appeared in all these areas. In contracting, one recommendation sought to dispel the parochial atmosphere:

- Include requirements and incentives for sharing information and products in all appropriate contracts.

In the policy area, recommendations called for coordination of personnel changes with spiral cycles and focusing program oversight on risk management plans instead of the amorphous notion of status versus plan. In the funding area, the September "Barriers" work group expressed the opinion that there were no policy barriers to writing contracts to implement EA and SD. Nonetheless, a number of far-reaching recommendations concerning funding were made by various groups:

- Work with Congress to improve the funding model for DoD projects.
- Synchronize funding decisions with anchor point milestones.
- Budget C2 programs in the aggregate (at the PEO level).
- Help financial managers understand the unique funding needs of EA/SD.
- Make risk mitigation funding both acceptable and available.

here's how to make teams work

Teamwork is a military hallmark. Without teamwork, battles are lost before begun. Consider the teamwork displayed by the movement of 176,000 troops on 4100 ships to accomplish the Normandy beachhead on D-Day. Despite this glorious history, acquisition more often seems an adversarial skirmish than a team working to accomplish a task. Of course, contractors have adversaries; this is guaranteed by the system of competitive bidding. The adversarial attitude has, too often, been carried forward into the execution of the contract, once awarded. Contractors are loath to share information with other contractors or even with the customer whose contract explicitly states a right to information.

Many efforts have been made to forestall adversarial interactions, notably "integrated product teams" formed from stakeholders including the acquirers, the contractors, the users, and many more. This concept has even been adopted as part of the Spiral Development Model. Nonetheless, it does not always work to the full satisfaction of all. Observing this, the work groups had many suggestions about teamwork and teamwork was a minor theme of the February presentations and a major theme of the September presentations.

Many specific recommendations were expressed. Among them, the most vital is that

IPTs should be given the authority to negotiate requirements, test strategy, and budget allocations

Other recommendations described steps to take to ensure a representative and engaged team. The plan for the team should include team-building efforts. If the team is distributed over a number of locations, it should have collaboration tools and various other recommended steps should be taken to maximize success.

and here's how to ensure use of EA and SD

Given the workshop enthusiasm for the spiral development method, it is not surprising that participants devoted attention to how to foster the use and growth of the method for military acquisition. Changing existing habits is always difficult. It does not help that the acquisition

process involves military personnel who can be "ordered" to do things in a given way and also contractors who can be contractually "bound" to do things in that same way. Neither stricture matters when people go off to do their actual work and revert to hoary-aged habits.

The emphasis on promulgation of EA and SD was evident in the workshops in that it was a presentation's theme in September, two categories of recommendation in February (Promote SD and Educate About SD), and a recommendation category in September. However, there were no really innovative ideas about how to accomplish the change, other than the work of the "Operationalization" group in September. The majority of the recommendations called for writing guidebooks, case studies, or other materials—all with no real incentives for people to actually read the results. A second, more promising, collection of recommendations looked at the longer term and suggested emphasis on SD in various courses that acquisition personnel may encounter, including universities, Professional Military Education (PME), Defense Acquisition University (DAU), and the Project Management Institute (PMI).

Other recommendations were to
- Deliberately build an SDM community.
- Provide a contract vehicle for EA/SD facilitators and mentors to support early adopters of EA/SD.
- Develop a cadre of industry and government people knowledgeable in the pragmatic application of EA and SD who are readily available to program offices and contractors.
- Pay greater attention to education and selection of integration practitioners.

The Real Situation

This discussion was prompted by a fairly cynical opinion, which can now be interpolated with a more realistic evaluation:

We don't understand EA and SD
> Although not widely understood, the definitions are well established.

and we aren't convinced they work,
> Real successes are documented, but systematic study is indeed needed.

but we want them anyway so here's how to

improve them, adapt the DoD, make teams work,
> The workshops produced valuable suggestions in all three of these areas.

and ensure their use.
> Additional documents may help, but education is the only real solution.

EA and SD provide good process models for acquisition by the military and development by contractors. These tasks are notoriously prone to descent on the slopes of Figure 10 to budget overruns, dilatory delivery, and ill-designed, poorly executed products. Thus EA and SD are worth pursuing for the promise shown by successful experiences reaching back, in some cases, over one or two decades.

As part of analyzing the recommendations for the above summary, one set of recommendations stood apart. These were the recommendations that a single focal point for EA/SD improvement/adoption be established. These recommendations called variously for an IPT, an office within SIS, or an outside organization. Whichever is established, its purpose should be to shepherd the recommendations of the workshop and other efforts at improving EA, SD, and their use in acquiring military systems. Such an office is imperative to avoid duplicate efforts and neglected opportunities. This office will serve as the single point of information on EA/SD acquisition policy, practice, and guidance. Project managers will come to see this office as the source of training materials they have used and the source of useful suggestions and tools they can apply to the current tasks.

These two spiral development workshops have generated interest in EA and SD, widened knowledge of their merits and applicability, and brought numerous suggestions for improvement of all these. As a result, and with the aid of the focal office recommended by the workshops, it is possible to foresee the general maturation of EA and SD leading to a time when projects are routinely economical, timely, and useful.

Returning to the triple apex problem of attaining early, cheap, good, we see that, in a sense, spiral development guarantees two of these. At the start of each iteration, risk analysis determines what is to be done and how long to take. Budget considerations are part of this, so nothing will be attempted which cannot be paid for. Given these constraints it may not be possible to meet all the requirements. That is, choosing spiral development is tantamount to accepting that full functionality may not be delivered by a given contract. No contract is thus a fixed price contract. The risk management team—composed of members from the contracting, acquiring and using communities—is responsible for delivery of as much as possible within the time and budget allotted. Thus with spiral development within evolutionary acquisition, the apex of success can always be attained!

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Appendix: Recommendations

This table lists the recommendations made by the work groups sorted according to class. For the full text of the recommendations, see the report above or the version on the Web site: <http://www.sei.cmu.edu/cbs/spiral2000/september/recommendations-sept00.xls>

Work Gp	Class	Agent	Recommendation	Due date
Definition	Adapt	SIS Office	Identify focal point in SIS Office for EA	Apr '01
Operationali-zation	Adapt	DoD	Appoint and fund an organization to serve as steward for ensuring the transition and adoption of EA/SD.	with release of 5000.2R
Mapping	Adapt	Ferguson, et al.	Convene an IPT to further the incorporation of SD within EA.	
Mapping	Adapt	PM	Plan each EA/SD project so consecutive spiral cycles converge toward a final goal … use anchor points or stable intermediate points.	
Mapping	Adapt	SIS Office	Depict EA so as to reveal the feedback possibilities instead of making it appear as a rigid linear approach.	
Mapping	Adapt	PEO	In applying EA/SD distinguish between Information Systems and Software Intensive Systems.	
Barriers - Contracting	Con-tract	DCMA	Develop contracting models and suggest incentives that match EA/SD models.	Sep '01
Barriers - Contracting	Con-tract	PM	Include requirements and incentives for sharing in-formation and products in all appropriate contracts.	
Mapping	Con-tract	PM	Avoid SD for the manufacture of any lot in programs with production phases.	
Barriers - Budget	Fund	OSD	Develop mechanisms to synchronize funding deci-sions with anchor point milestones.	with release of 5000.2R
Barriers - Budget	Fund	OSD and the Ser-vices	Budget C2 programs in the aggregate (at the PEO level).	start with '02 BES
Barriers - Budget	Fund	OSD and the Ser-vices	Promote understanding of unique funding needs of the EA/SD programs by the financial management community.	with release of 5000.2R
Barriers - Risk Aver-sion	Fund	PEO	Make risk mitigation funding both acceptable and available.	each project
Barriers - Stakeholders	Fund	PM	Program budgets must include funding for participa-tion of stakeholders in program activities.	
Barriers - Risk Aver-sion	IPT	Senior Leadership	Senior leadership should demonstrate support for EA/SD through participation in spiral development integrated product teams (SDIPT).	each project

Work Gp	Class	Agent	Recommendation	Due date
Barriers - Risk Aversion	IPT	OIPT	Focus program oversight on the program manager's risk mitigation plans.	each project
Barriers - Stakeholders	IPT	OSD	Update IPT language to include a broader definition of "stakeholder" for spiral development projects.	
Barriers - Stakeholders	IPT	PM	The number of IPTs that require end-user support must be limited so members can be empowered and knowledgeable.	
Barriers - Stakeholders	IPT	PEO, PM	IPTs should be given the authority to negotiate requirements, test strategy, and budget allocations.	
Barriers - Education	Study	FFRDCs	Develop representative risk patterns and their associated mitigation process models to show which patterns are best suited to EA/SD.	Feb '01
Barriers - Education	Study	Services	Validate EA/SD models through industry and government pilot projects as part of the Simulation Based Acquisition Initiative.	Sep '01'
Barriers - Education	Study	SIS Office	SEI should be tasked to produce a case study/examples document.	Sep '01
Definition	Study	SIS Office	Document experiential case studies	Apr '01
Strategies	Study	C3I and AT&L	Develop and disseminate detailed case studies of EA and SD.	
Strategies	Study	Ferguson	Identify and prototype effective ways to facilitate the sustained engagement of the stakeholder communities.	
Mapping	Study	Etter with SAEs	Explore EA further prior to imposing it as a policy. Evaluate how current programs would have fared under EA. Conduct a prototype study.	
Barriers - Education	Train	OSD	Provide a contract vehicle for EA/SD facilitators and mentors to support early adopters of EA/SD.	Oct '01
Barriers - Education	Train	OSD	Require that EA/SD curricula be incorporated in Professional Military Education (PME) and Defense Acquisition University (DAU) for stakeholders as well as acquisition professionals.	Feb '02
Definition	Train	SIS Office	Use definitions to develop an insert that can be put into 5000 Directives, Regulations, and Instructions.	Oct '00
Definition	Train	SIS Office	Develop implementation guidance for existing publications, e.g., AFI 63-123.	Apr '01
Definition	Train	SIS Office	Develop guidebook for PMs and PEOs addressing "top 25" implementation questions.	Apr '01
Definition	Train	DSMC	Develop education and training modules for insertion into Acquisition Management courses.	Aug '01
Strategies	Train	SIS Office	Develop a cadre of industry and government people knowledgeable in the pragmatic application of EA and SD who are readily available to program offices and contractors.	

Acronyms

This list omits names of organizations that are spelled with all upper case letters.

AC2ISRC	Aerospace C2ISR Command (Air Force)
ACAT	Acquisition Category
ACTD	Advanced Concept Technology Demonstration
AF	Air Force
AFB	Air Force Base
AFI	Air Force Instruction
AFIA	Air Forces Information Agency
AFOTEC	Air Force Operational Test and Evaluation Center
ASC	Aeronautical Systems Center
ASCON	Associate Contractor
AT&L	Acquisition, Technology, and Logistics (a Undersecretary of Defense)
ATD	Advanced Technology Demonstration
BES	Budget Estimate Submission
C2ISR	Command and Control, Intelligence, Surveillance, and Reconnaissance
C4I	Command, Control, Communications, Computers, and Intelligence
CAOC	Combined Air Operations Center
CBO	Congressional Budget Office
CeBASE	Center for Empirically Based Software Engineering
CECOM	US Army Communications-Electronics Command
CIO	Chief Information Officer
CJCS	Chairman, Joint Chiefs of Staff
CMM	Capability Maturity Model
CMMI	Capability Maturity Model Integration
CMU	Carnegie Mellon University (home of SEI)
COTS	Commercial-Off-The-Shelf

CSE	Center for Software Engineering (USC)
CSM	Center for Systems Management
DARPA	Defense Advanced Research Project Administration
DAU	Defense Acquisition University
DC	District of Columbia
DCMA	Defense Contract Management Agency
DCMC	Defense Contract Management Command
DD-21	a class of destroyers for the 21st century (U.S. Navy)
DNA	DeoxyriboNucleic Acid
DoD	Department of Defense
DoDI	DoD Instruction
DSCOPS	Deputy Chief of Staff for Operations and Plans
DSMC	Defense Systems Management College
DUSD	Deputy Under Secretary of Defense
EA	Evolutionary Acquisition
EA/SD	Evolutionary Acquisition and Spiral Development
EMD	Engineering and Manufacturing Development
ESC	Electronic Systems Command (Air Force)
ESP	Evolutionary Spiral Process (Software Productivity Consortium)
FAA	Federal Aviation Agency
FAQ	Frequently Asked Questions
FFRDC	Federally Funded Research and Development Center
FSCV	Future Scout Combat Vehicle
FY	Fiscal Year
GAO	Government Accounting Office
GOTS	Government-Off-The-Shelf
IA	Incremental Acquisition
IDA	Institute for Defense Analysis
IDIQ	Indefinite Delivery Indefinite Quantity (a type of contract)
IEEE	Institute for Electrical and Electronic Engineers
INCOSE	International Council on Systems Engineering

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IOC	Initial Operating Capability
IPPD	Integrated Product and Process Development
IPT	Integrated Product Team
ISR	Intelligence, Surveillance, and Reconnaissance
JAD	Joint Application Development
JEFX	Joint Expeditionary Forces Experiment
JSF	Joint Strike Fighter
JWE	Joint Warfare Exercise
LCA	Life Cycle Architecture
LCO	Life Cycle Objectives
MAJCOM	Major Command (USAF)
MBASE	Model-Based Architecting and Software Engineering
NASA	National Aeronautical and Space Administration
NSF	National Science Foundation
OIPT	Overarching Integrated Product Team
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OUSD	Office of the Under Secretary of Defense
OUSD/AR	OUSD / Acquisition Reform
OSD/PA&E	OSD / Program Analysis and Evaluation
PEO	Program Element Officer
PM	Program Manager
PME	Professional Military Education
PMI	Program Management Institute
PMO	Program Management Office
POM	Program Objectives Memorandum
PPBS	Planning, Programming, and Budgeting System
QFD	Quality Function Deployment
RDT&E	Research, Development, Testing and Evaluation
ROI	Return On Investment
RUP	Rational Unified Process

SA-CMM	Software Acquisition Capability Maturity Model
SA/SD	Structured Analysis/Structured Design
SAE	Service Acquisition Executive
SAF	Secretary of the Air Force
SAF/AQ	SAF/Acquisition
SAF/AQI	SAF/Acquisition: Information Dominance
SAIC	Science Applications International Corporation
SD	Spiral Development
SDIPT	Spiral Development Integrated Product Team
SDM	Spiral Development Model
SEI	Software Engineering Institute (CMU)
SEIR	Software Engineering Information Repository
SIS	Software Intensive Systems
SMC	Space and Missile Systems Center (Air Force)
SPAWAR	Space and Naval Warfare Systems Command
SPC	Software Productivity Consortium
SPO	System Program Office
SR	Special Report
SW-CMM	Software Development CMM
TACOM	Tactical Command
TMA	Too Many Acronyms
TSPR	Total System Performance Responsibility (a type of contract)
UML	Unified Modeling Language
US	United States
USAF	United States Air Force
USC	University of Southern California (home of CSE)
USD	Under Secretary of Defense
USD/AT&L	USD/Acquisition, Technology, and Logistics
WG	Work Group (of the workshop)
WRAP	Warfighter Rapid Acquisition Process (SAF/AQ)

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13. ABSTRACT (MAXIMUM 200 WORDS)

The evolutionary acquisition strategy has been promulgated by the forthcoming DoD Instruction 5000.2. It introduces innovations throughout the acquisition cycle: before a contract is considered, technology readiness guides the choice of experiments; contracts are let for one or more blocks; and progress within each block is managed with spiral development. There is some confusion as to the nature of evolutionary acquisition and spiral development and their relationship. To address these problems, a workshop was held September 13-15, under joint sponsorship of the Deputy Under Secretary of Defense for Science and Technology, the Software Engineering Institute, and the Center for Software Engineering. This report summarizes the workshop and presents its recommendations.

Themes appearing in the workshop presentations included the lack of understanding of the definitions of evolutionary acquisition and spiral development, some extensions to these definitions, the barriers imposed by existing funding and contracting policies, the need for teamwork among all stakeholders, and the role of education and training in acculturation. Work groups at the workshop recommended specific actions aimed at building and spreading a culture for evolutionary acquisition and spiral development. These actions can be grouped under the topics of improvements to contract models, revision of funding approaches, adaptation of acquisition policies, enhancement of integrated product teams, training and acculturation of participants, and studies of evolutionary acquisition and spiral development to validate and improve them.

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